Design and Analysis of the Automated Metrological System for the Kingdom of Saudi Arabia

by

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THE UNIVERSITY OF PETROLEUM AND MINERALS

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DESIGN AND ANALYSIS OF THE AUTOMATED METEOROLOGICAL SYSTEM FOR THE KINGDOM OF SAUDI ARABIA

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SAMEER ABDULELAH BUKHARI

THESIS

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This thesis, written by

SAMEER ABDULELAH BUKHARI

under the direction of his Thesis Committe, and approved by all its members, has been presented to and accepted by the Dean, College of Graduate Studies, in partial fulfillment of the requirements for the degree of

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COLLEGE OF GRADUATE STUDIES
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بسم الله الرحمن الرحيم

والصلاة والسلام على أشرف الخلق والمرسلين

" وقل ربي زدني علما" "

صدق الله العظيم

أهدي هذه الرساله الى والديّ العزيزين

This Thesis is dedicated to my dear parents.

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LIST OF ABBREVIATIONS

ADP	Automatic Data Processing
AFTN	Airways Facilities Transmission Network
AIREPS	In-flight Air Craft Reports
BCT	Bulletin Construction Table
CDB	Climate Data Base
CLIMAT	Climatic Observation
CRT	Cathode Ray Tube (same as VDU)
DTG	Data Time Group
GTS	Global Telecommunication System
HF	High Frequency
HZN	Regional Broadcast
IMCAGS	Integrated Meteorological Communications and Graphic System
MCC	Main Communications Center
MCS	Main Computer Software
MDT	Message Descriptor Table
MEPA	Meteorological and Environmental Protection Administration
METARS	Meteorological Airdrome Reports
METEOSAT	European Space Agency Meteorological Satellite
MFO	Main Forecast Office
MODEM	Modulation Demodulation
MSS	Message Switch
NMEC	National Meteorological and Environmental Center
NOAA	National Oceanographic and Atmospheric Administration (US)
OAS	Objective Analysis
RAREP	Weather Radar
RCC	Regional Collection Center
ROFORS	Route Forecasts
SAVID	System for Analysis Verification and Interactive Display
SPECI	Special Observations
SYNOP	Synoptic Observation
TAFS	Terminal Aerodrome Forecasts
TEMP	Upper Air Reports
UA	Upper Air
VDU	Video Display Unit
WMO	World Meteorological Organization

ABSTRACT

Analysis of the Old Saudi Arabian Meteorological System is introduced. An alternative system is designed and analyzed in data handling, processing and forecasting areas.

In almost all the cases operational limiting factors were alleviated by selecting from the various options the most proper one. The initial cost of implementing modern technology was partially offset by manpower redistribution.

However, the total cost was increased by required higher skill levels of personnel and commitment to long-term maintenance of sophisticated equipment.

1.0 INTRODUCTION

1.1 OVERVIEW

The Kingdom of Saudi Arabia established a General Directorate of Meteorology in 1966. This organization was a sector of the Ministry of Defence and Aviation and was responsible for making weather observations, issuing weather bulletins, preparing weather forecasts, and providing weather briefings for aircraft flight operations. The headquarters of this organization was established in Jeddah.

The increasing industrialization of the Kingdom, the development of agriculture in an arid environment, the increased levels of shipping and oil transport, which is vulnerable to severe weather and sea conditions on the Arabian Gulf and the Red Sea, and greatly expanded aircraft operations within the Kingdom placed increasingly severe demands on the Directorate for information and services.

In 1980, the role of the General Directorate was expanded to include the general environment and the name was changed to the Meteorological and Environmental Protection Administration (MEPA). The increased demand for services and the expansion of the organization's role into Environmental Protection forced an examination of the way in which the organization conducted its mission to determine whether and how operations could be improved to meet the demands.

The principal problems identified in this review were:

a) Utilization of the large amount of observational data available from in-country and international sources.

b) The limited manpower and skill resources currently available to the organization.

c) The satisfaction of users with the accurate and timely data and analysis products generated by the organization.

d) The necessity of organizing diverse historical data files to make them available to potential users.

e) The ability to interface with international weather and environmental organizations and services, utilizing high technology observation, communications and analysis systems.

1.2 THESIS STATEMENT

The application of electronic automatic data processing technology to meteorological message processing and data analysis should improve the timeliness, accuracy, and quality of products produced by the Directorate.

In an attempt to solve or reduce the previously mentioned problems, the design of a new meteorological data handling system is proposed which will consist of:

a) The automatic reception, editing and formatting of meteorological data messages by using an electronic digital message switch (MSS) which will provide not only the speed and the proper storage area but also will be capable of handling additional data messages from Saudi Arabian weather observation stations as well as a large volume of other additional message data.

b) A reduction in the number of personnel required for message coding, decoding and assembly, thus allowing for a re-distribution of personnel to be more gainfully utilized in the areas of forecasting and environmental analysis.

c) Using the digital computers for switching the messages, providing automatic plotting (graphics) capabilities and as a tool for making meteorological data analyses. This will promote the more timely delivery of the data products generated by the department and should increase the accuracy of the results.

d) Establishing a historical data base to store and retrieve meteorological data that will provide the meteorologists with a tool to retrieve historical data files and to perform analysis functions necessary for forecasting, research projects, and environmental monitoring and modeling.

e) Having readily accessable historical data base will provide the ability to exchange data with other international communities, and MEPA staff will have the opportunity to improve their skills as well as having the opportunity and the experience of transferring the technology into an operating system.

1.3 PROJECT MANAGEMENT

My first responsibility in this project was as a member of the MEPA Technical Committee. The Committee's purpose was to survey the existing meteorological system to identify shortfalls and formulate recommendations to eliminate the deficiencies. An exhaustive analysis was accomplished to select the most appropriate options which were consolidated into a technical proposal. Five companies responded to the public tender. After careful study of each proposal for technical compliance, professional competance and cost; we selected the prime contractor for the total upgrade project. This first phase is illistrated in Figure 1-1. (1)

In the second phase of the project, as shown in Figure 1-2, I served as the overall Project Manager. My responsibilities were to procure the physical facilities and supervise the equipment installation which included testing and acceptance for MEPA. A major task was to monitor the Company's actions and to insure contract compliance, and to negotiate the settlement of unforeseen problems which arose during the implementation.

The operational and final phase is shown in Figure 1-3. I am currently Director of the Data Center and am responsible for the automated data processing required for data handling, meteorology, climatology and MEPA administrative functions.

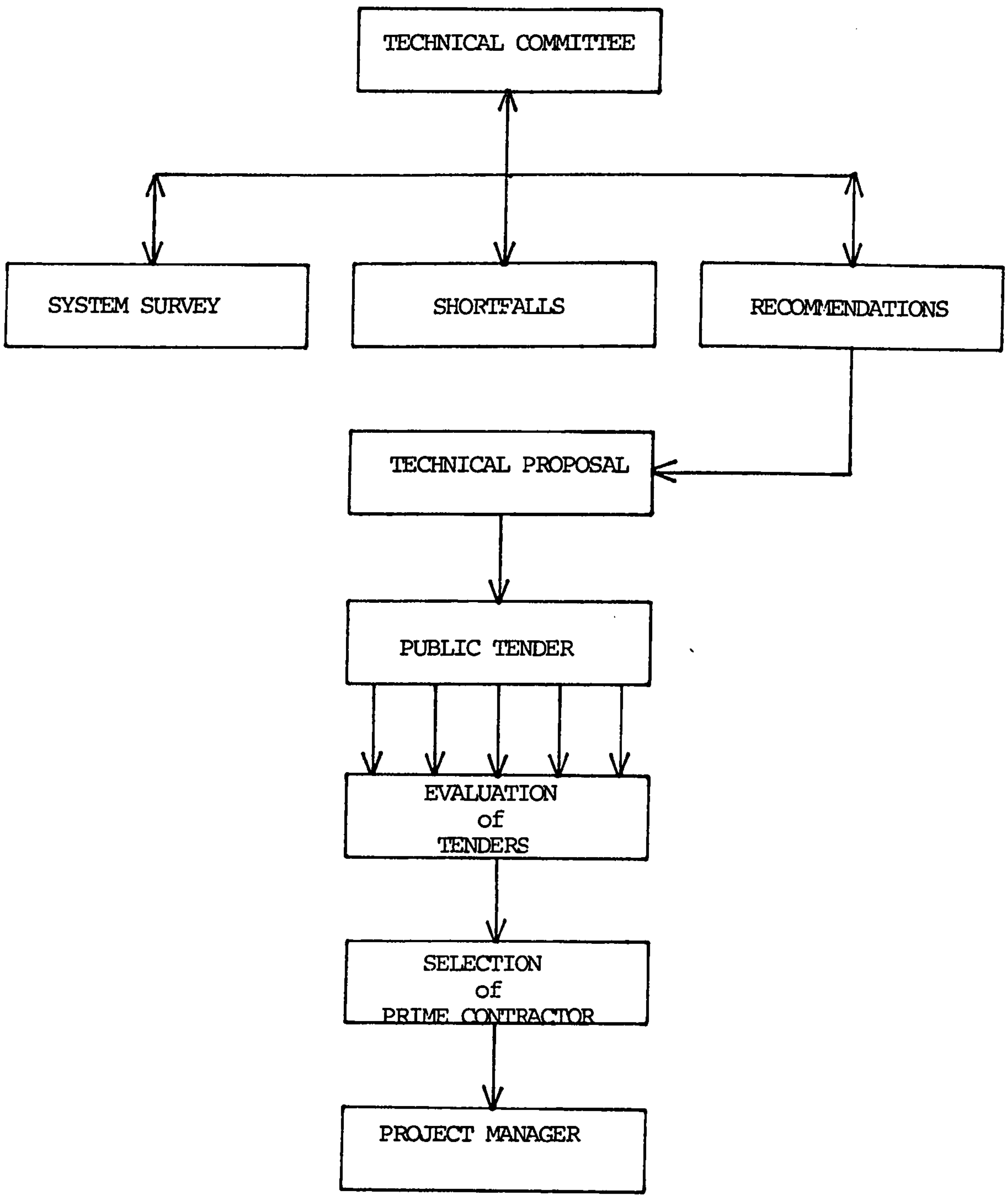


FIGURE 1-1

PROJECT MANAGEMENT, PHASE I

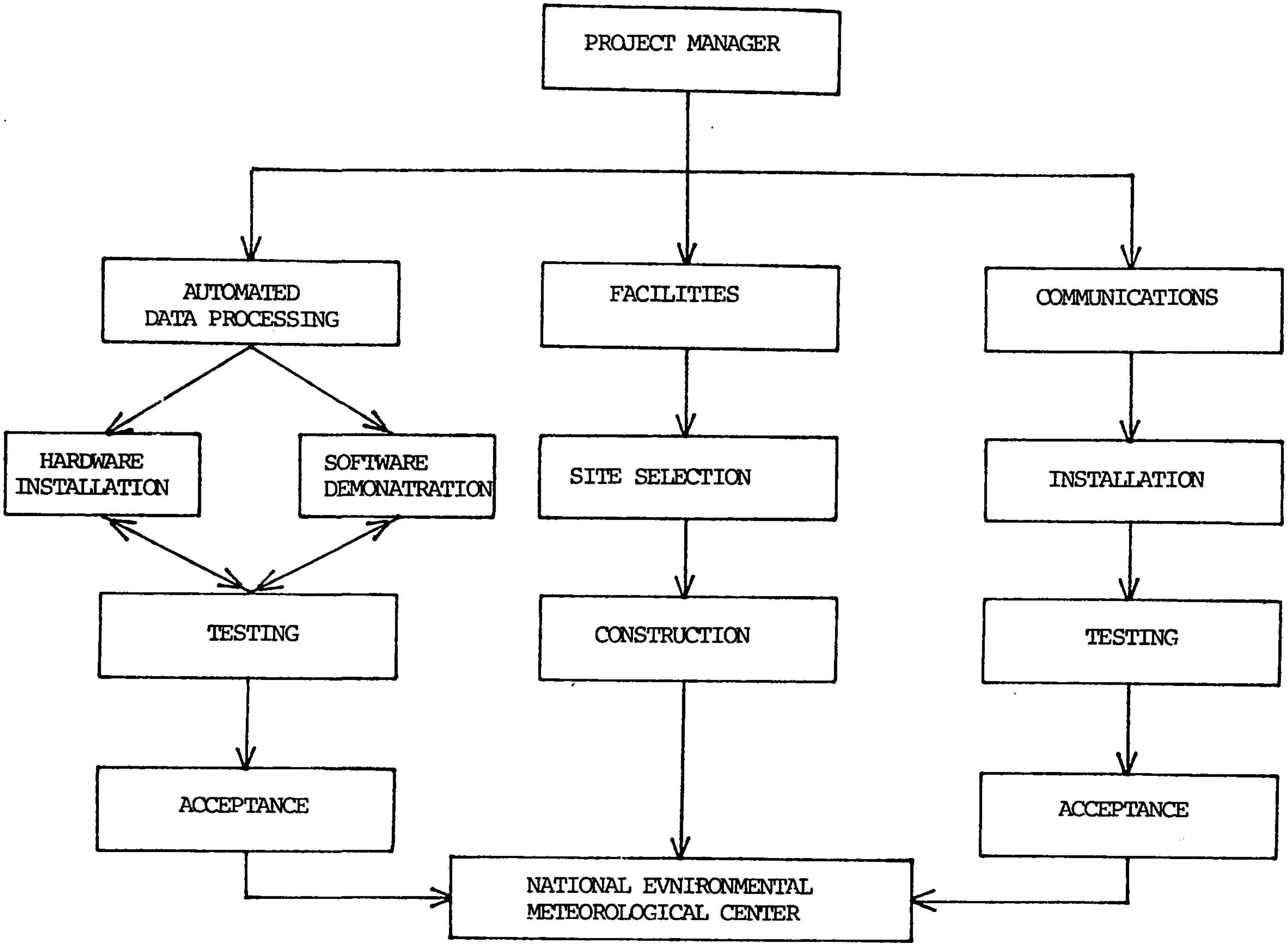


FIGURE 1-2

PROJECT MANAGEMENT, PHASE II

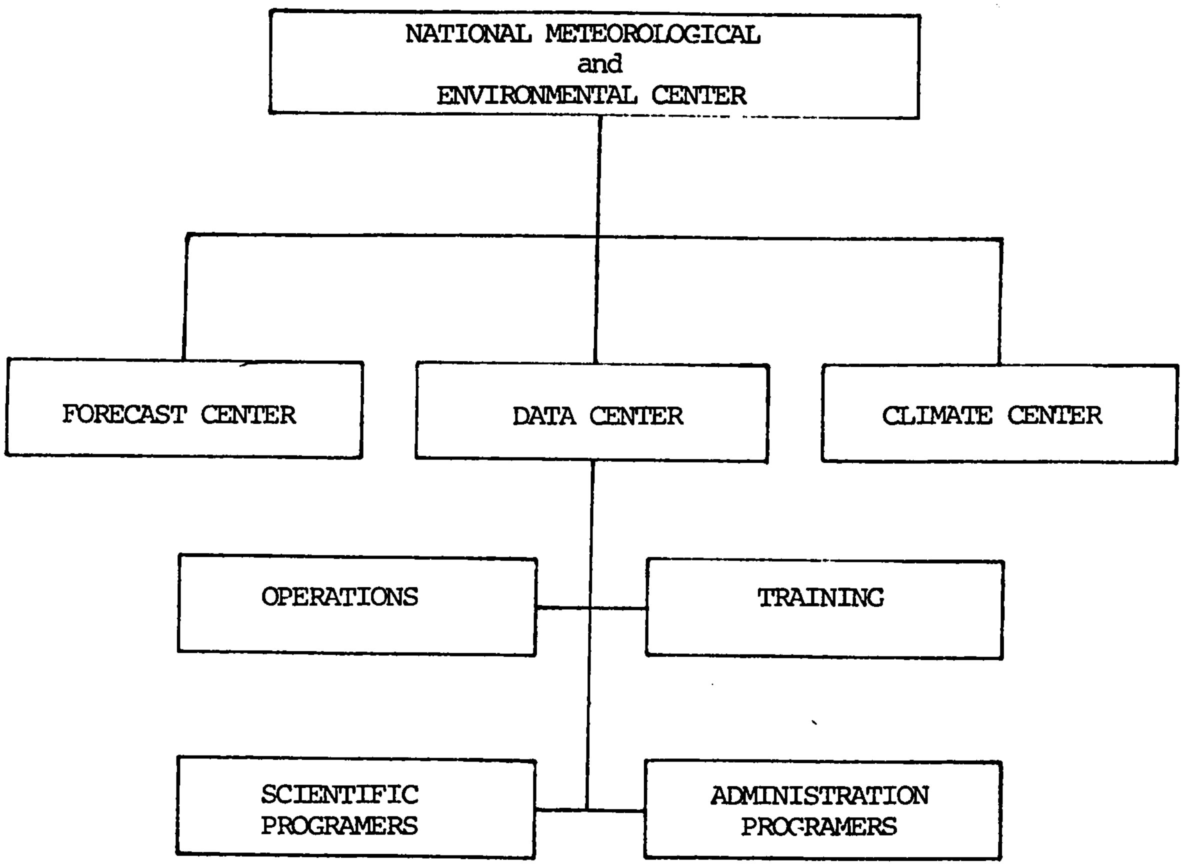


FIGURE 1-3

PROJECT MANAGEMENT, PHASE III

2.0 EXISTING MANUAL METEOROLOGICAL DATA HANDLING SYSTEM

2.1 SYSTEM DESCRIPTION

This section describes in detail the meteorological data handling system of the Meteorological and Environmental Protection Administration as it existed up until the beginning of 1981.

a) System Components

The Saudi Arabian Meteorological Observation Station Network is made up of twenty-two manned observer stations. Table 2-1 is a list of station names, WMO* station numbers, and reporting codes (aerodrome identifier).

Most of the observing stations are located on or near airports. Each one reports observations to a regional center. Figure 2-1 shows a map of the station locations and the regional center each station reports to.

The main function of each station is to observe and report hourly weather conditions (METARS). At three and six hour intervals more complete data are taken to create a SYNOPTIC weather report. Eleven stations are equipped to make upper air soundings with radiosondes, and six can make weather radar observations. Table 2-2 is a list of the observations made at each station.

* WMO is the World Meteorological Organization. WMO is based in Geneva, Switzerland and acts as a consultative body to the 97 member countries. Saudi Arabia is a member of the WMO.

TABLE 2 - 1

STATION IDENTIFICATION CODES

WMO NUMBER	STATION NAME	REPORTING CODE
Northern (Central) Region		
40375	*Tabuk	OETB
40400	Al Wajh	OEWJ
40361	Al Jouf	OESK
40356	Turaif	OETR
40357	Badana	OEBD
40362	Rafha	OERF
40373	Quaisumah	OEPA
Western Region		
40477	*Jeddah	OEJD
40430	Medina	OEMA
40480	Taif	OETF
40439	Yanbu	OEYN
Eastern Region		
40438	*Riyadh	OERY
40416	Dhahran	OEDR
40394	Hail	OEHL
40405	Gassim	OEGS
	Hofuf	
Southern Region		
40569	*Khamis Mushait	OEKM
40568	Abha	OEAB
40498	Bisha	OEBH
40572	Gizan	OEGN
40570	Najran	OENG
40495	Sulayel	OESL

* Regional Centers

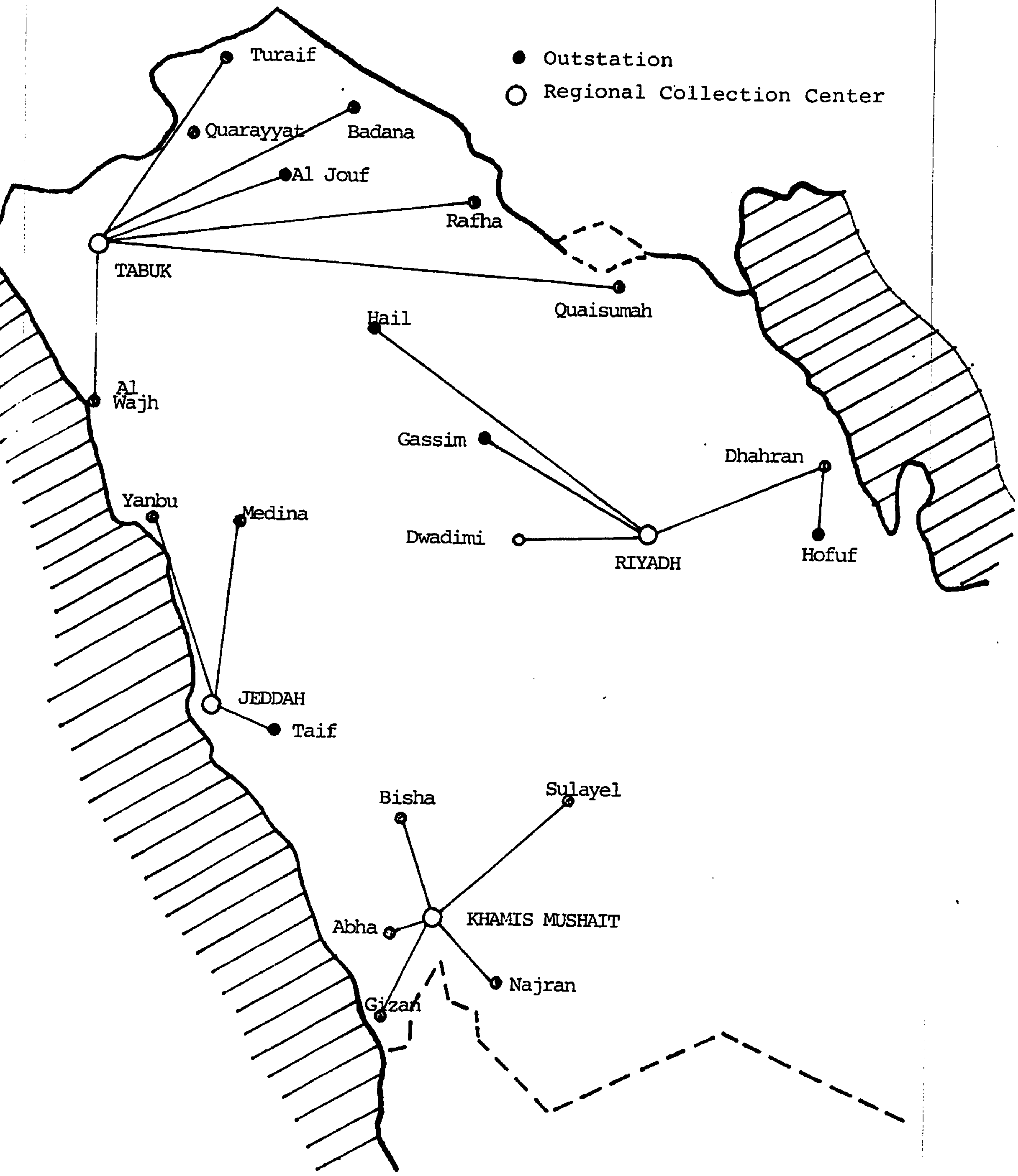


FIGURE 2-1
MANNED METEOROLOGICAL STATIONS IN SAUDI ARABIA

STATION	TYPE	W	T	T_d	P	P_w	V	SUN	UA
ABAH	OBS	X	X	X	X	X	X		
AL JOUF	OBS	X	X	X	X	X	X		
AL WAJH	OBS	X	X	X	X	X	X	X	X
BADANA	OBS	X	X	X	X	X	X	X	
BISHA	OBS	X	X	X	X	X	X	X	
DHAHRAN	OBS	X	X	X	X	X	X	X	X
GASSIM	OBS	X	X	X	X	X	X		
GIZAN	OBS	X	X	X	X	X	X		X
HAIL	OBS	X	X	X	X	X	X		
JEDDAH	MCC	X	X	X	X	X	X	X	X
KHAMIS MUSHAIT	RCC	X	X	X	X	X	X	X	X
MEDINA	OBS	X	X	X	X	X	X		X
NAJRAN	OBS	X	X	X	X	X	X		
QUAISUMAH	OBS	X	X	X	X	X	X		X
RAFHA	OBS	X	X	X	X	X	X		
RIYADH	RCC	X	X	X	X	X	X	X	X
SULAYEL	OBS	X	X	X	X	X	X		X
TABUK	RCC	X	X	X	X	X	X	X	X
TAIF	OBS	X	X	X	X	X	X	X	X
TAURAIF	OBS	X	X	X	X	X	X	X	
YANBU	OBS	X	X	X	X	X	X		

LEGEND

OBS = OBSERVATION STATION
RCC = REGIONAL COLLECTION CENTER
MCC = MAIN COMMUNICATIONS CENTER
W = WIND SPEED/DIRECTION
T = TEMPERATURE
T_d = DEW POINT TEMPERATURE
P = PRESSURE
P_w = PRECIPITATION
V = VISIBILITY
SUN = SOLAR RADIATION
UA = UPPER AIR

TABLE 2-2

STATIONS VS. PARAMETERS

The basic duties of each synoptic observation station is to prepare and transmit a complete synoptic observation. An observation must consist of the following parameters:

a) Air Temperature
b) Average Wind Speed
c) Average Wind Direction
d) Station Atmospheric Pressure
e) Dry and Wet Bulb Temperatures
f) Precipitation
g) Visibility Estimate
h) Cloud Cover
i) Unusual Weather

The World Meteorological Organization has established goals for meteorological data accuracy. The following is list of a number of synoptic parameters showing the desired accuracy of observation. (2)

1. Cloud cover estimate to within $\pm$ 0.1 total sky cover.
2. Cloud base height in meters $\pm$ 10%
3. Direction of cloud movement to $\pm$ 10°
4. Atmospheric pressure $\pm$ 0.1 millibar
5. Pressure tendency, $\pm$ 0.2 millibar
6. Dry bulb temperature, $\pm$ 0.1°C
7. Temperature extremes, $\pm$ 0.5°C
8. Wet bulb temperature, $\pm$ 0.1°C
9. Humidity, $\pm$5% to 50%, $\pm$ 2% over 50%
10. Wind direction, $\pm$ 10° for 10 minute average
11. Wind speed, $\pm$ 0.5 m/sec up to 5 m/sec, $\pm$ 10% above 5 m/sec
12. Precipitation, $\pm$ 0.2 mm up to 10 mm total

13. Duration of sunshine, $\pm$ 0.1 in any hour
14. Intensity of sunshine, $\pm$ 1 $cal/cm^2/hour$
15. Visibility, $\pm$ 10% of visual range.

Certain other information is calculated by the observer.

a) Sea level atmospheric pressure
b) Barometer pressure tendency, and
c) humidity.

The observer must have certain skills and a minimum training level so that he can make observations that are accurate and record them in a permanent record. If the initial observation is not accurate, all of the rest of the complex systems for distributing and manipulating data is wasted. The mechanical equipment for making measurements must be kept in good working order and calibrated to make accurate measurements.

The upper air sounding stations in the Kingdom are synoptic stations equipped with additional special equipment to measure the flow of wind, atmospheric pressure, humidity and temperature at higher elevations in the atmosphere by using balloons. The balloon has a radiosonde transmitter attached to it, and by using reference navigation signals from three known earth stations and using special tracking equipment, the exact position of the balloon can be measured ($\pm$ 10 meters), and by plotting the position versus height it is possible to calculate the speed and direction of air flow at upper levels in the atmosphere and also obtain the pressure, humidity and temperature at that height.

b) Data Flow Analysis

A drawing of the observers radio equipment is shown in Figure 2-2. The flow of data in the meteorological data acquisition system is shown in schematic form on Figure 2-3. The process begins with the meteorological observer at an observation station. This section describes the data flow paths from observer to users.

The duty of the weather observer is to acquire and log weather observations. Weather observations are made through instrumental and qualitative measurements. Thus, the observer creates a permanent record of observations taken in a prescribed manner. Basically, he manually records a set of observations hourly on the hour, and special observations for any significant changes in certain weather elements every three hours or, if necessary, when they occur. This permanent record form (station observation log) is sent monthly by mail to the Regional Collection Centers (RCC), where it is manually checked and corrected if possible, for consistency, reasonableness, and procedural, or computational errors. It is then forwarded to the headquarters in Jeddah to be archived (stored in a room, which has been serving as the climate data base repository).

In this form, the existing climate data base has been difficult to access easily so that the data can be made available to users. Each year, the twenty two manned observation stations generate 264 station observation logs, which are 40 cm x 70 cm sheets

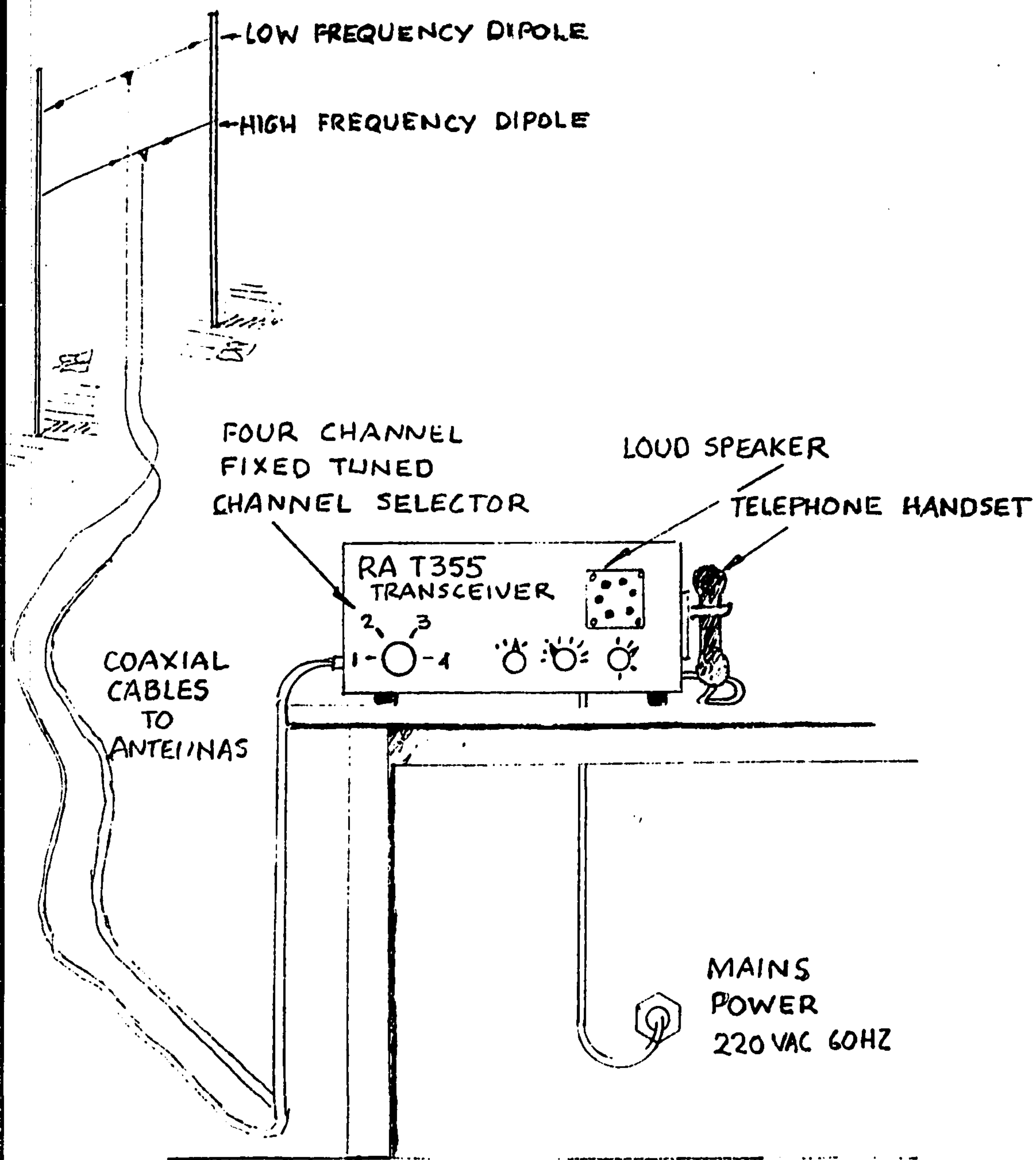


FIGURE 2-2

EQUIPMENT CONFIGURATION

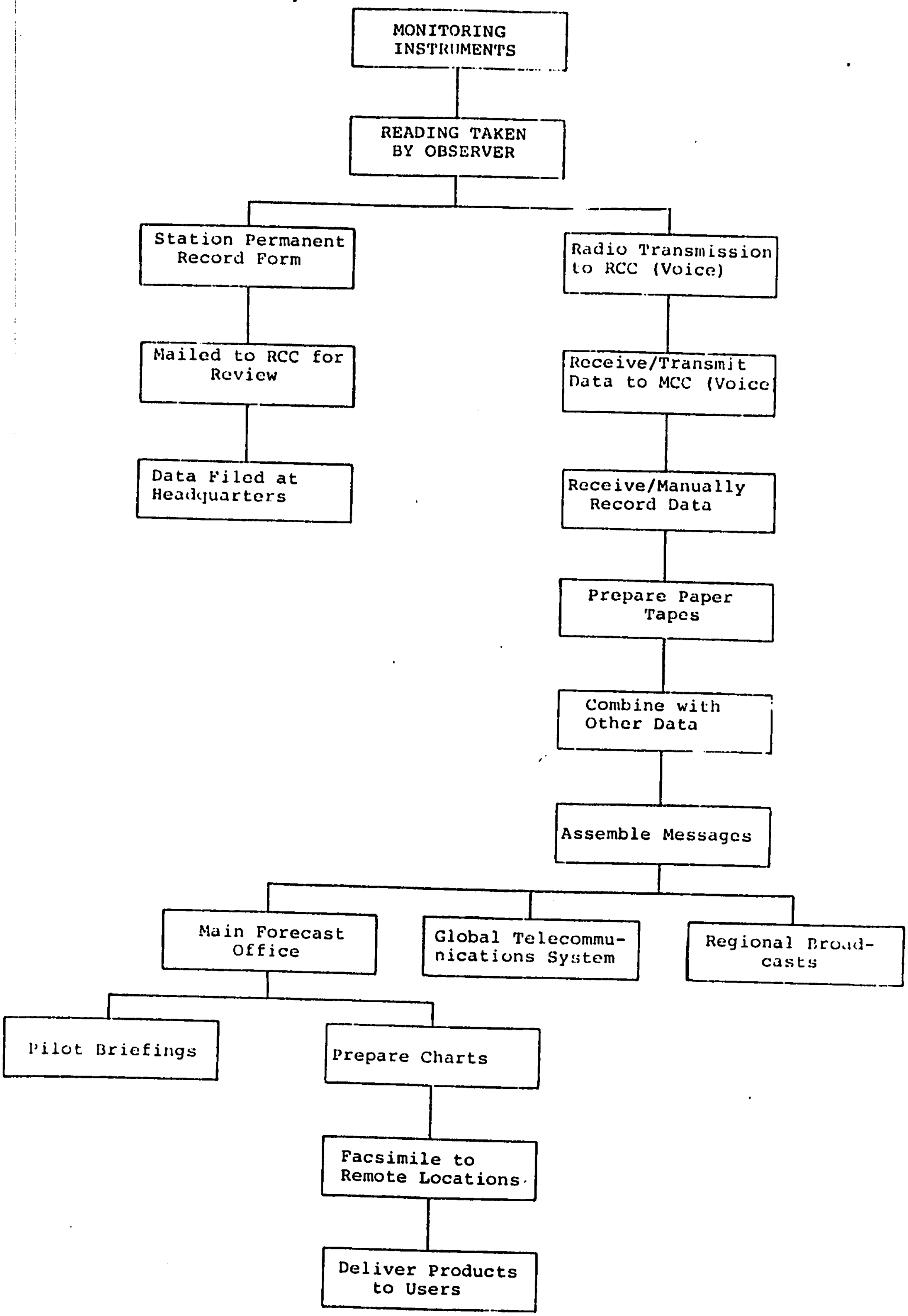


FIGURE 2-3
DATA FLOW ANALYSIS

containing the observer's hand recorded data for a total of some two million (2,000,000) numerical values.

This data flow is shown on the left side of the schematic diagram.

In addition to the manual data record, the data are also forwarded by the observer to a collection center, and from there they are relayed to another location where it is assembled with other data and utilized. This data flow path is shown on the right hand side of the schematic diagram.

The weather observer assembles his observations into a standard WMO Code for transmission by voice communication from his station to a Regional-Collection-Center (RCC), using high frequency radio. From the RCC, the data are relayed to the Jeddah Main Communication Center (MCC) using additional high frequency radio voice communication circuits. Knowing that weather data is perishable information and that data utility rapidly diminishes with time, a weather communication network not only must be reliable but also should transmit data rapidly. The existing Kingdom's weather communication system is not only relatively slow but each relay point may introduce errors into the data. The first transmission is from the observing weather station to the RCC by voice using radio circuits. The Regional Operator manually records the reports from all his outstations and then relays the compiled data listings to the MCC in Jeddah, again by voice via radio where the data are again manually recorded by a receiving operator.

In addition to the time consuming and potential error producing procedures at those locations, reports are frequently totally lost due to high frequency radio propagation limitations that occur almost daily between some geographic locations in Saudi Arabia.

At the MCC an operator makes a visual inspection of the received and recorded observations for format errors, which, if detected are corrected if possible. Errors in meteorological content can seldom be corrected even if detected. Only the original observer can validate the data. The data are then passed to a teletype operator who punches a paper tape for each observation message and assembles the message tapes to form the content of required bulletin collectives. An operator prepares a paper tape header for each separate bulletin. These tapes are then fed into the radio transmission circuits in the proper sequence and on predetermined frequencies to create the weather bulletins that are required by users.

Bulletins are transmitted back to the regional centers for subsequent relay to individual stations, transmitted as regional broadcasts for radio intercept by other countries, entered into the Global Telecommunication System (GTS) to fulfill the World Meteorological Organization commitments, and sent to the main forecast office (MFO) in Jeddah.

At this point: about 40 minutes have elapsed since the time of observation, significant errors may have been introduced, and considerable desired data may be missing. The data are often received too late by the GTS for use by the world's major automated meteorological centers. The centers normally start their analysis programs by data time plus 25 to 40 minutes. Missing data creates voids in such programs and results in data limited forecasts in the Saudi Arabian area. When the final message data are received at MFO it must be decoded and hand plotted by an observer.
A highly skilled observer can plot five surface reports per minute and one of average skill, about three per minute. The base chart which is used by the MFO averages a total of 250 station plots and so requires 50 to 80 minutes total plotting time. Now a minimum of one and one half hours have elapsed before the data are prepared for the forecaster.

c) <u>Data Output Products</u>

The data from the worldwide observing station network is the basic information used for all meteorological and environmental applications. Even the most sophisticated processing systems are limited by the amount, correctness and timeliness of such data. Meteorological data can be grouped into message forms which are used to serve three broad categories:

1. Required for realtime decisions, such as aircraft operations.

Aircraft operators must have weather observation for take-off, landing and enroute hazards to guarantee the safety of flight. Examples of weather information required, are scheduled hourly surface observations, meteorological airdrome reports (METARS) which are supplemented by special observations (SPECI). When critical parameters pass through defined thresholds; weather radar reports (RAREP); and in-flight aircraft reports (AIREPS) are utilized.

2. To build a data base for meteorological analysis and prognosis.

   The basic reports for this effort are: synoptic observations (SYNOP) which are taken every six hours and are more comprehensive than the hourly METAR's. SYNOP's are supplemented by three-hourly reports which are in SYNOP format. Another report type is upper air reports (TEMP). The output from real time and historical data base analysis predict meteorological parameters at some future time and are used for decision assistance for a variety of human activities.

3. To construct a climatological data base which is a systematic archive of all types of meteorological observations.

   These data are processed to determine mean, normal, and extreme values of meteorological parameters. Applications are used as planning factors for a multitude of activities that range from vacation planning to feasibility studies for large scale industrial and agricultural projects.

2.2 SYSTEM PERFORMANCE EVALUATION

This section presents the results of a review of the performance of different parts of the meteorological message handling system. The purpose of this review is to establish reasonable estimates of the message volume handled by the system, the manpower devoted to this process, the frequency of errors generated by the system and a qualitative assessment of output product quality as related to the timeliness and accuracy of the final data.

a) Message Handling Capacity

Jeddah Main Collection Center for Saudi Arabian meteorological data receives an average of 23 messages per hour from the three in-country Regional Collection Centers plus three direct message reporting stations. Three radio transmitting stations are monitored at all times to receive the 252 daily messages for a daily total message group count of 5,520 data groups. Procedural messages on this network also flow in both directions, requesting corrections, retransmissions, and frequency control, plus administrative traffic.

The out-of-country meteorological data is continuously received by monitoring 10 radio channels and 5 land lines. The quantity of received data is an order of magnitude greater than the Kingdom's data. An average of 144 meteorlogical messages are received each hour, which translates into 3,464 daily messages with a total group count of 146,040.

Distribution requirements for the edited Saudi Arabian and selected out-of country data are satisfied by 5 outgoing teletype circuits and 4 high frequency radio broadcasts. A total of 5,100 messages are transmitted daily that contain a total of some 400,000 data groups. Table 2-3 shows a breakdown of the individual circuit origin and destination with data group counts. A unique problem arises with the AFTN circuit because it is a general aviation circuit and not a dedicated meteorological data circuit. Consequently meteorological related messages must be manually extracted from a large volume of incidental aeronautical and administrative traffic.

b) Manpower Requirements

The entire meteorological data communications system is very labour intensive. Table 2-4 shows the manpower required, listed by skill, required in the system. The observers at each observing site are not included since communications are a relatively small proportion of their total duties. The annual payroll cost for meteorological data handling is more than SR 6 million. Even not considering training and other overhead costs, it is apparent that routine meteorological data handling is expensive. (3)

c) Data Error Analysis

For the purpose of this evaluation it is assumed that the original observations are absolutely correct. This is not a realistic assumption, but the training, motivation, supervision of observers, and instrument calibration and servicing are separate

AVERAGE RECEIVED MESSAGES/GROUP COUNT
FROM INTERNATIONAL STATIONS

STATION	LANDLINE Messages/Day		HF BROADCAST Messages/Day		AVERAGE GROUPES PER MESSAGE		TOTAL GROUPS PER DAY	
	I/C	O/G	I/C	O/G	I/C	O/G	I/C	O/G
Delhi	600	400	0	0	60	60	36,000	24,000
Cairo	0	0	400	800	60	80	12,000	64,000
Kuwait	32	400	0	0	10	80	320	32,000
Baghdad	20	350	0	0	10	80	200	28,000
PT Sudan	32	400	0	0	10	80	320	32,000
HZN	0	0	0	800	0	80	0	64,000
AFTN	500	350	0	0	40	80	20,000	28,000
Sanna	0	0	40	800	20	80	800	64,000
Aden	0	0	40	800	10	80	400	64,000
Moscow	0	0	600	0	60	0	36,000	0
Wien-1	0	0	700	0	30	0	21,000	0
Wien-2	0	0	100	0	30	0	3,000	0
Kano	0	0	100	0	40	0	4,000	0
Nairobi	0	0	100	0	40	0	4,000	0
Paris	0	0	100	0	40	0	4,000	0
Rome	0	0	100	0	40	0	4,000	0
TOTAL	1,184	1,900	2,280	3,200	-	-	146,040	400,000

I/C = In-coming messages
O/G = Out-going messages

TABLE 2-3

MANPOWER

MAIN COMMUNICATION CENTER (MCC) MANPOWER	
RADIO OPERATORS	41
COMMUNICATION ENGINEERS	6
TAPE CUTTERS (TELETYPE OPERATORS)	14
EDITORS	18
ADMINISTRATION SECTION	10
TOTAL MCC	89
REGIONAL COLLECTION CENTERS (RCC)	79
WEATHER FORECASTERS	180

TABLE 2-4

problems that are not included in this evaluation since they are not affected by the data handling system.

Estimated error rates by source are shown in table 2-5. Errors can be introduced at each point of human intervention and by poor radio or line quality. Major sources of error are; radio propagation, voice diction, tape punching, and transcription. The total estimated error rate in any Saudi Arabian data passed through the system is 10%. Consequently, 90% is correct when used for operational purposes. Even more significant, an average of 25% of the desired data are totally missing due to local radio wave propagation effects, lack of back-up facilities problems at observatories. The most serious effect is that the data user cannot normally distinguish between correct and incorrect data, and applies both with the same confidence.

d) Output Product Quality

The quality of output user products is directly proportional to input data dependability and timeliness. Error correction and avoidance is of no value, if those procedures are so time consuming that when the data are finally applied, it is too old to be of practical value. As previously stated weather data is a very perishable commodity. Even if the present system could be made error free, the data are generally received too late by the world's major meteorological centers for scheduled computer processing. When the Kingdom has developed its own computer-based forecast center, it will still be dependent upon prognostic data

ESTIMATED ERROR RATES

RADIO PROPAGATION	6.0 %
VOICE DICTION	1.0 %
TAPE PUNCHING	1.5 %
TRANSCRIPTION	1.5 %
TOTAL	10 %

Missing Data (Propagation) 25 %

* The estimated error rates were obtained from MEPA Communications Operators.

TABLE 2-5

fields created by a major regional center such as Offenbach, Germany. The in-country forecasting system cannot be upgraded without timely and correct input data.

Output product quality is limited by five major factors:

1. Original data quality
2. Availability of data at the right time
3. Quantity of available data not used because of time limits
4. Variable skill levels of different forecaster, and
5. Extreme difficulty in retrieval of historical data.

e) Archiving Climate Data

Poor timeliness of data has no adverse impact on archiving data for climatology purposes. However, archived data that contains a known significant error rate cannot be used with confidence. Statistically, climate data should be no worse than 95% error free to be of dependable practical value.

The use of original handwritten records and storage methods which are difficult to manage place severe limitations on the availability of data for research and analysis purposes. To use the existing data base requires labor intensive tasks of an administrative nature.

f) Summary and Conclusions

The operating communications and data handling system have been reviewed to establish the details of the functions performed, the manpower and skill levels required, the equipment utilized, and the methods employed. This review has established the current system performance level. The demands on this system have slowly increased over a period of years. The construction of new airports in the Kingdom has increased the number of observatories, and the increase of national and international air traffic has increased the demands for accurate and timely forecast services. An additional impact has been the growth of international communications systems to exchange weather data within regions and on a global scale. The forecast process has been steadily improved both by a growth in the technology and by new equipment available to the forecaster.

At the present time, the system limitations which have the greatest effect on the demands to be satisfied by the MEPA are:

1. Acquisition of in-country data within a time period where it can be used by the forecaster and exchanged with other users in the region.

2. The limited quantity of available data that can be included on a synoptic map which is prepared manually.

3. The accuracy of data furnished to the forecaster.

4. Low weather forecast reliability due to slow manual procedures and non-availability of modern meteorological technology. Shown in Appendix A are examples of manually plotted surface and upper air charts.

5. The extreme difficulty of accessing historical climate data making it almost useless.

6. Lack of trained manpower.

3.0 AUTOMATED METEOROLOGICAL DATA HANDLING SYSTEM DESIGN

In order for the General Directorate to meet its operational goals in supplying accurate, timely meteorological and environmental data, a faster, more reliable and accurate data handling system must be designed and developed. In addition, available new technologies must be introduced in order to support and expand the data resources.

The first step in the design process is to identify those activities which presently limit the achievement of goals and select a replacement that more nearly meets the requirements.

The following are the major limiting system performance factors of the existing data acquisition and distribution network. Following the statement of the factor several options are listed. These options, if selected, could remove or materially reduce the limitation. There is a threshold value for some of the limitations. That is, they do not need to be reduced to zero or expanded indefinitely but only to a predictable level.

LIMIT 1 - Time Interval Required for In-country Data Collection

Reasons : Outstations report data by HF voice operated circuits, data are manually recorded and forwarded through additional voice channels.

Options : a) Divide the network into smaller segments to permit parallel rather than serial operation.

b) Replace voice channels by teletype machines to eliminate manual data recording and increase transmission speed.

c) Replace voice channels by store and forward digital system to increase transmission speed.

d) Replace radio channels with landlines.

LIMIT 2 - High Data Error Rates (Including missing data)

Reasons : Misunderstanding voice transmissions, recording data incorrectly, HF circuit noise, fading, and propagation factors.

Options : a) Alternate mode of HF transmission to reduce noise and to operate reliably at marginal signal levels.

b) Alternate paths. Greater flexibility in choice of frequency.

c) Employ telephone circuits or communication satellite circuits to improve voice quality.

LIMIT 3 - Total System Message Handling Capacity

Reasons : Message handling by voice and manual transcription consumes all of the schedule time.

Options : a) Increase operating staff and communications circuits.

b) Substitute automatic data processing systems to reduce message transmission, sorting, and assembly time of the existing system to allow time for new message additions.

LIMIT 4 - Timeliness of Outgoing Messages

Reasons : Sorting and message assembly is performed manually.

Options : a) Increase operating staff and divide tasks into parallel operations to reduce the period of time required.

b) Use electronic data processing equipment to automatically sort and assemble messages.

c) Re-evaluate data request and limit services to priority.

LIMIT 5 - Timeliness and Reliability of Synoptic Forecasts

Reasons : Late of limited observational data, tedious manual map plotting, forecasting by manual approximation techniques in lieu of mathematical solution using physical laws.

Options : a) Obtain high speed Global Telecommunications System (GTS) link to replace low speed 10 radio intercept circuits and 5 low speed land lines.

b) Obtain satellite imagery data.

c) Automate data recording and map plotting.

d) Automate analysis of all atmospheric parameters.

e) Obtain computer generated prognoses of atmospheric parameters from GTS.

LIMIT 6 - Loss or Delay in Storage and Retrieval of Climate Data

Reasons : Inconvenient record format for identification and storage; manual transcription required to separate parameters. Retrieval and analysis are labor intensive.

Options : a) Modify format and improve manual recording procedures.

b) Reduce record volume by transfer of data to film.

c) Archive data on magnetic tape for ADP retrieval and processing.

d) increase work force to correct errors, provide rapid data retrieval, and to analyse the data.

In order to evaluate the various options, a weighted factor comparison is made. For the purpose of this evaluation the total data handling and processing system is sub-divided into three major components; data transfer, forecasting, and climatology. A different set of evaluation factors are applied to each function. For all options the factors are evaluated against the existing system. The rating of each factor in the existing system is 1 and all of the factors are increased, decreased or are unaffected by adopting an option. A number of these limiting factors are interactive, as are the options available to counter them. The options are not all equally applicable and so a weighing scheme is introduced to equalize the advantage or disadvantage of each particular option. If the option affects the system adversely, the weighing factor is assessed as a penalty. Conversely, a credit is applied if the factor is beneficial to the system.

Seven factors were chosen to evaluate data transfer:

1. Data input time.
2. Error rate of data.
3. Total message capacity
4. Product output schedule
5. Initial cost
6. Changes in manpower requirements
7. Changes in long term maintenance requirements.

The general constraints are:

1. Changing the input data threshold is generally the result of an action taken for another reason. Therefore even if advantageous, it is not weighted.

2. Decrease in the error rate of the throughput of the system are given a benefit of 20 percent.

3. Increases in system capacity are a benefit but of medium priority and generally the result of actions taken for other purposes rather than expressly for increasing capacity. Therefore, they are not weighted.

4. Those options which bring the system performance below a desired threshold are weighted positively. The major improvement would be decreasing the time of a function (or the sum of the overall function times). The benefit is plus 30 percent.

5. Added cost is not a critical factor and so it is not weighted, but is included in options comparisons.

6. Limited skilled manpower, particularly at remote locations, is a major consideration. Where manpower is increased as part of an option, a penalty of 40 percent is assessed against the gain realised through the option.

7. Long term maintenance requirements also have a penalty assessed because of the added difficulty in furnishing the skilled manpower, obtaining spare parts, the addition of consumables, etc. The penalty for significant increase in maintenance requirement is 40 percent.

Tables 3-1, 3-2, 3-3 and 3-4 have been prepared to show the results of the comparison of options in limits 1 through 4. On the top of the figure is a time line diagram which shows each stage in the real time data flow. Each discrete point in the system is identified by a letter. The symbol to represent the time and action is completed at that point. t4 is the time when the required data is available for routine message distribution to the GTS and to Saudi Arabian users. Eight factors were chosen to evaluate the analysis and forecasting cycle:

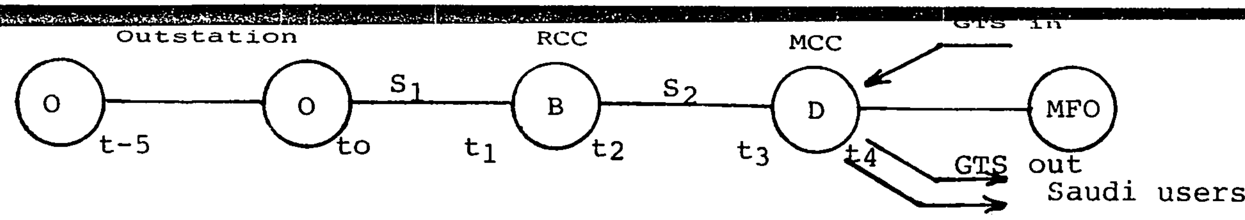
1. Through-put time
2. Data coverage
3. Technology level
4. Initial cost
5. Manpower requirements for changes
6. Changes in long-term maintenance
7. Forecast reliability
8. System capacity

The general contraints are:

1. The individual functions are not mutually exclusive. Some overlap of functions occur and elapsed time is not the sum of all activities. Any reduction in total time increase the utility of the final product significantly. Therefore, it is weighted at the 20 percent level.

2. Adequate data coverage is of paramout concern but does not affect the final forecast products enough to warrant a magnification.

3. The level of available technology used in meteorological systems is a sound predictor of the value of the output products. It is not weighted.



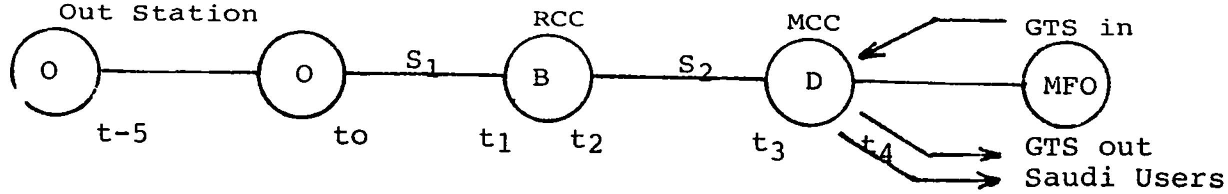
FUNCTION	S_1	B	S_2	D		SUM			Timeliness in	error rate	capacity	time output	initial cost	manpower	maintenance	sum
EXISTING	8	5	4	10		27		EXISTING	1	1	1	1	1	1	1	7
OPTIONS																
1A MULTIPLE	2	2	1	10		15	1A	INITIAL	.25	1	.5	.55	1.8	1.6	1.8	
CIRCUITS								WEIGHTED	.25	1	.5	.38	1.8	2.24	2.52	8.60
1B TELETYPE	2	3	2	6		13	1B	INITIAL	.25	.9	.8	.48	1.2	.8	1.4	
								WEIGHTED	.25	.72	.8	.34	1,2	.48	1.96	5.75
1C STORE AND	2	2	1	7		12	1C	INITIAL	.25	.9	.5	.44	1.2	.6	1.4	
FORWARD								WEIGHTED	.25	.72	.5	.31	1.2	.36	1.96	5.30
1D ELIMINATE	2	0	0	3		5	1D	INITIAL	.25	.7	.4	.18	2.4	.4	.6	
RADIO								WEIGHTED	.25	.56	.4	.13	2.4	.24	.36	4.34

Function Time in Minutes / Fractional Change

TABLE 3-1

EVALUATION OF LIMIT 1

* Function Times given above were provided by experts in the field.



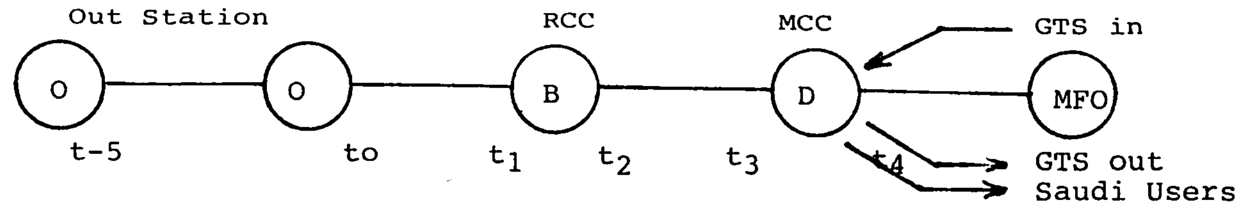
Function Time in Minutes

Fractional Change

FUNCTION	S_1	B	S_2	D	SUM		Timeliness in	error rate	capacity	time output	initial cost	manpower	maintenance	sum
EXISTING	8	5	4	10	27	EXISTING	1	1	1	1	1	1	1	7
OPTIONS														
2A ALTERNATE	6	4	3	8	21	2A	.75	.9	1	.78	1.4	1	1.2	
HF MODE							.75	.72	1	.54	1.4	1	1.68	7.09
2B ALTERNATE	8	5	4	10	27	2B	1	.9	1	1	2.5	1	.6	
PATHS (CHOICE OF FREQUENCIES)							1	.72	1	1	2.5	1	.36	7.58
2C NON-RADIO	7	5	3	10	25	2C	.88	.95	1	.93	3.0	1	.7	
VOICE							.88	.76	1	.65	3.0	1	.42	7.71

TABLE 3-2
EVALUATION OF LIMIT 2

* Function Times given above were provided by experts in the field.

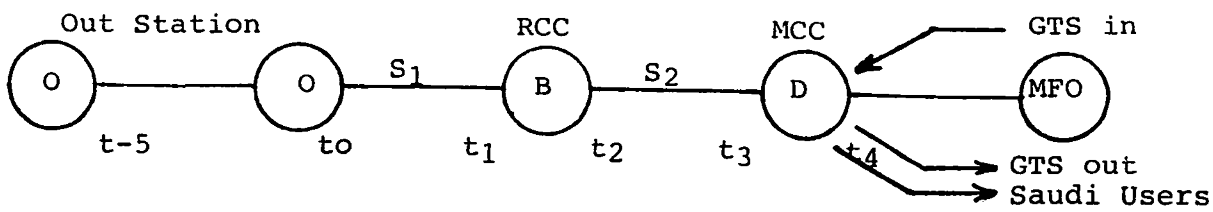


FUNCTION	S_1	B	S_2	D		SUM			Timeliness in	error rate	capacity	time output	initial cost	manpower	maintenance	sum
EXISTING	8	5	4	10		27		EXISTING	1	1	1	1	1	1	1	7
OPTIONS																
3A INCREASE	4	2	2	5		13		3A	.5	1	.8	.48	1.5	2	1.2	
STAFF									.5	1	.8	.34	1.5	2.8	1.68	8.62
3B ADP	8	5	4	1		18		3B	1	1	.8	.67	2.2	.5	1.2	
									1	1	.8	.47	2.2	.24	1.68	7.39

Function Time in Minutes — Fractional Change

TABLE 3-3
EVALUATION OF LIMIT 3

* Function Times given above were provided by experts in the field.



Function Time in Minutes

FUNCTION	S_1	B	S_2	D		SUM
EXISTING	8	5	4	10		27
OPTIONS						
4A INCREASE	-	-	-	5		
STAFF						
4B ADP	-	-	-	1		
4C LIMIT	-	-	-	9		
SERVICE						

Fractional Change

	Timeliness in	error rate	capacity	time output	initial cost	manpower	maintenance	sum
EXISTING	1	1	1	1	1	1	1	7
4A	1	1	1	.5	1	1.8	1	
	1	1	1	.35	1	2.52	1	7.87
4B	1	.9	.4	.1	2.0	.25	1.2	
	1	.9	.4	.07	2.0	.15	1.68	6.2
4C	1	1	1.5	.9	1	1	1	
	1	1	1.5	.63	1	1	1	7.14

TABLE 3-4

EVALUATION OF LIMIT 4

* Function Times stated above were provided by experts in the field.

4. Same cost considerations are used as in the previous factors, and cost is not weighted.

5. The weighting function is 40 percent penalty for for increased manpower.

6. The same maintenance weighting is used as before. The weighting penalty is 40 percent for increased maintenance.

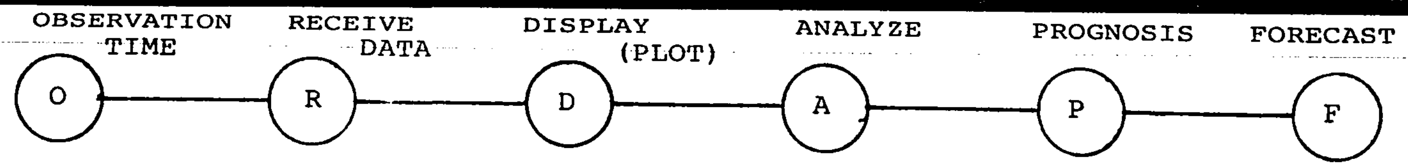
7. The most important factor of the entire system is forecast product reliability. Therefore a weighting function of 40 percent is assigned.

8. The existing system cannot meet all the Kingdom's forecast requirements. Therefore, any increase in capacity is recorded with a 20 percent weight.

Table 3 - 5 shows the results of the evaluation of the Limit 5 options. The diagram at the top depicts the sequence of discrete functions and a letter is assigned to identify each one. Nine factors were chosen to evaluate climatology:

1. Missing data rate
2. Data error rate
3. Initial cost
4. Data retrieval and acessibility
5. Data display
6. Computational capability
7. Study and evaluation capability
8. Manpower
9. Maintenance

The general contraints are:



FUNCTION	R	D	A	P	F	ELAPSED TIME		Thru-put time	Data Coverage	Technology level	Initial cost	Manpower	Maintenance	Forecast Reliability	Capacity		Sum
EXISTING	4	3	4	4	3	10	EXISTING	1	1	1	1	1	1	1	1		8
GTS LINE	2	3	4	4	3	8	INITIAL	.8	.6	1	1	1	1	.9	1		
							WEIGHTED	.64	.6	1	1	1	1	.54	1		6.78
SATELLITE	4	3	4	4	3	9	INITIAL	.9	.6	.9	1.5	1.2	1.1	.8	1		
							WEIGHTED	.72	.6	.9	1.5	1.68	1.54	.48	1		8.48
AUTO PLOT	4	.5	4	4	3	8	INITIAL	.8	1	.9	1.2	.7	1.1	.9	.8		
							WEIGHTED	.64	1	.9	1.2	.42	1.54	.54	.64		6.88
AUTO ANAL.	4	3	1	4	3	8	INITIAL	.8	1	.9	1.3	.7	1.1	.8	.7		
							WEIGHTED	.64	1	.9	1.3	.42	1.54	.48	.56		6.84
AUTO PROG.	4	3	4	.5	3	7	INITIAL	.7	1	.7	1.4	.7	1.1	.5	.5		
							WEIGHTED	.56	1	.7	1.4	.42	1.54	.3	.4		6.32
ALL OPTIONS	2	.5	1	.5	3	6	INITIAL	.6	.4	.3	2.4	.5	1.4	.2	.3		
							WEIGHTED	.48	.4	.3	2.4	.3	1.96	.12	.24		6.20

FUNCTION IN HOURS — FUNCTIONAL CHANGE

* Function Times given in this table were estimated by experts in the field

TABLE 3-5
EVALUATION OF LIMIT 5

1. Significant missing data will invalidate a climatic study. Ninety five percent of available data must be used in meaningful statistical analysis. Any effort to obtain that threshold of data is benefited by a 30 percent weighing function.

2. Incorrect data has the same effect as missing data in creating a bias in statistical analysis and so is awarded a 30 percent weighing function.

3. Initial cost, manpower, and maintenance has the same affect and same weights as the previous sections.

4. Complete and correct archived climatic data is of no value if it is not accessible. Retrieval is weighted at 30 percent.

5. Retrieved data must be tabulated or plotted in a manner to facilitate analysis. Display improvements are rated at 10 percent.

6. Existing system is dependent on manual statistical analysis. Increased capability is required. The importance is reflected by a 10 percent benefit weighing function.

7. All factors combined to produce completed climatic application. The most important single factor then is to increase study capability, and therefore is rated at 40 percent.

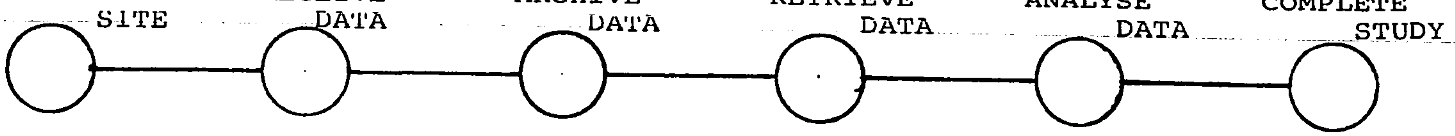
Table 3-6 shows the results of the evaluation of limit 6 options. The top line of the diagram depicts the sequence of the climatology functions. Each step is dependent and none is time critical in the real-time sense, but only as time affects the efficiency of the total system output.

Analysis conclusions:

Limit 1 : Time interval for in-country data collection. Option d) is clearly the best choice. Connecting each observing site directly to the main collection center by telephone line would solve time of data collection problem, reduce the error rate, and eliminate the need for the sub-collection centers. However, the Post Telephone and Telegraph could not support the project. The alternative of option c) is far superior than the other two choices. The digital store and forward system is used in the new system.

Limit 2 : High data error rates. The comparison summation of all the options exceeds that of the existing system due primarily to initial cost. The most advantageous option is an alternate mode of HF transmission which will operate more reliably at marginal signal levels.

Limit 3 : Total system message handling capacity. Both options have a significant initial cost and long-term maintenance load. The ADP option is clearly superior due to a large manpower reduction as opposed to a 100 percent increase with option a)



	OBSERVATION	RECEIVE DATA	ARCHIVE	RETRIEVE	ANALYZE	COMPLETE STUDY		MISSING DATA RATE	ERROR RATE	INITIAL COST	ASSESSIBILITY	DISPLAY	COMPUTATIONAL CAPABILITY	STUDY CAPABILITY	MANPOWER	MAINTENANCE	SUM
NOT TIME CRITICAL							EXISTING	1	1	1	1	1	1	1	1	1	9
							OPTIONS										
							6A IMPROVE	.9	.9	1	1	1	1	1	1.1	1	
							MANUAL PROCE-	.63	.63	1	1	1	1	1	1.54	1	8.8
							DURE										
							6B ARCHIVE	1	1	1.1	.9	1	1	1	1	1.1	
							ON FILM	1	1	1.1	.63	1	1	1	1	1.54	9.27
							6C ARCHIVE ON	1	1	1.2	.5	.7	.5	.4	1	1.2	
							MAGNETIC TAPE	1	1	1.2	.35	.63	.45	.24	1	1.68	7.55
							6D INCREASE	.9	.9	1	.8	1	.9	.9	2.0	1	
							WORK FORCE	.63	.63	1	.56	1	.81	.54	2.8	1	8.97

TABLE 3-6
EVALUATION OF LIMIT 6

<u>Limit 4</u> : <u>Timeliness of outgoing messages.</u> Even with the penalty for long-term maintenance, ADP is by far the most appropriate option for data sorting, message preparation, and transmission.

<u>Limit 5</u> : <u>Timeliness and reliability of synoptic forecasts</u>. All options compare very favourably with the existing system except receiving satellite data. That vital option comes only with a great investment in initial cost, manpower, and long-term maintenance. All options are incorporated in the system design.

<u>Limit 6</u> : <u>Loss or delay in storage and retrieval of climate data</u>. Three of the four options compare favourably with the existing system. However, we see again that the ADP option is certainly the best selection to remove the system's limiting factors.

Therefore the following are the major elements of a system that are introduced to provide improved system performance.

1. Replace the manual-voice data collection system in the Kingdom with a 75 baud automatic digital data transfer network.

2. Replace the manual incoming message reception operation with a computer based message switching system with automatic partial review of data accuracy and completeness.

3. Replace the manual outgoing message assembly operation with a computer based message assembly and automatic transmission of messages at scheduled times.

4. Provide a computer assisted forecast operation that will automatically plot synoptic weather maps.

5. Establish a computer based historical data base for automatic accumulation and rapid retrieval of data.

6. Add facilities for the utilization of meteorological satellite information to assist forecasting and climate information activities.

7. Design and furnish suitable facilities to house and utilize the upgrade equipment and systems efficiently.

3.1 PREDICTED ADVANTAGES OF THE AUTOMATED SYSTEM

It has been established in section two that the present data acquisition and handling system is labor intensive, schedule limited and includes errors because of multiple, serial, manual operational procedures.

The system should provide at least the following advantages:

a) By replacing the manual voice data collection system by an automatic digital data transfer system, the errors that are due to human intervention, line quality, and radio propagation can be significantly be reduced from 10 percent to less than 5.0 percent.

b) Replacing the manual incoming message reception operation by an automatic computer message switching system will give the flexibility to handle significantly more data with a 50% reduction in message handling manpower. These received data messages will be checked for valid header, format and construction which will ensure that only acceptable messages will be processed.

c) Replacing the manual outgoing message assembly operation by an automatic computer based message assembly will allow the re-distribution of these messages in an orderly and timely manner so other world meteorological centers can receive it in time to make maximum use of it. This will be accomplished with reduced manpower. The time required for message assembly will be reduced from 10 minutes to a few seconds each hour.

d) Utilizing the computer to plot synoptic weather maps will replace most of the current highly labor intensive and cumbersome hand plotting and will improve the quality of these plots. The automatic plot can be produced in several minutes instead of two hours. This saving in time will permit additional plots for different pressure levels to be prepared. At present, time and manpower do not permit this data assembly.

e) By developing a computer based historical data base all station observing records (data) will be available on magnetic tapes or discs which will provide the meteorologists with a tool to almost instantly retrieve historical data files to perform analysis functions necessary for forecasting, research projects, environmental evaluations and modeling applications. This will replace the current system of manual location, retrieval and copy-over of original data records.

f) Utilization of meteorological observation satellite information (imagery) will give an extra tool to the forecaster which will reflect upon the quality of the weather prediction. This is new information service that is not currently available.

3.2 COMPONENT DESIGN

This section provides a description of the system components that are proposed to be assembled. It also presents the major decision factors that were used in making the selection.

a) Outstation Data Acquisition and Transfer

It has been known that numerous errors may be introduced into observation data by manual recording and voice transmission of data messages. It has also been established that radio propagation effects result in a significant error rate or complete data loss. In addition, a manually polled high frequency voice communications network requires a significant portion of each hour just to transfer the data to the user.

These shortcomings could be overcome if the system allowed the observer to: encode the data in message form so he could review it for completeness before it is transmitted, send the data by code rather than voice, and transmit the code messages at rate somewhat faster than normal voice communication speeds.

The system adopted will use a keyboard operated Video Display Unit (VDU). This will permit the observer to type a message on the unit viewing screen and check it for accuracy and proper format. The VDU is an electronic terminal that encodes letters and numbers into a binary code (5 level). Once the data message has been entered on the screen, it may be edited by the observer to assure proper format and be checked for accuracy. (4)

The electronic version of the message is held in a data register in the VDU and, on command, can be sent as a serial data bit stream, eliminating the need for voice transmission of the data. The binary encoded data is to be sent from the observation station to its destination by high frequency radio circuits. These circuits are subject to changes in radio wave propagation causing fading, and to interference from unwanted signals from other sources. To help overcome these effects, the signals will be encoded using an audio tone scheme that is designed to have selective circuits to reject random interference and to operate on normally marginal signal strength levels. Since the encoded signal has to be decoded, the electronic unit must be reversible. This function is supplied by a Modulation-Demodulation circuit, abbreviated to MODEM. (5)

In order to reduce the time required to establish communications and pass traffic between stations, an automated calling and reply system is to be included in the upgraded equipment. With this system, the radio receiver will normally be in a "monitor" mode. A distant transmitting station will broadcast a call consisting of a three number sequence. Each receiving station has a decoder and when it decodes its own code number, will automatically send the message stored in the VDU by the operator.

By incorporating the automatic call and respond system it will also be possible to transmit messages to a receiving station. The messages can be directed to the VDU screen to be seen by the operator and a small electronic printer will be attached so that a permanent copy of the message is made at the receiving station.

Because there are times when it is desirable to establish voice transmission between stations, equipment for improving this service is to be added to the system. The main improvement will be to add a speech compression circuit. This circuit modifies the electrical signals generated by a microphone to increase the power factor of the speech signal. This increase in speech power helps compensate for low received signal levels or adjacent channel interfering signals picked-up by the receiver. (6)

A drawing of the proposed equipment assembly is shown on Figure 3-1. A schematic diagram of the function of each of the components is shown on Figure 3-2. Figure 3-2 is drawn to show the receive function on the left of the center line and the transmit function on the right. Those circuits (or components) used for both transmission and reception cross the center line. The arrowheads on the signal flow lines show the direction of travel. Receiving paths are from top to bottom, transmission paths are from bottom to top. (7)

FIGURE 3-2A is a list of the communications equipment hardware.

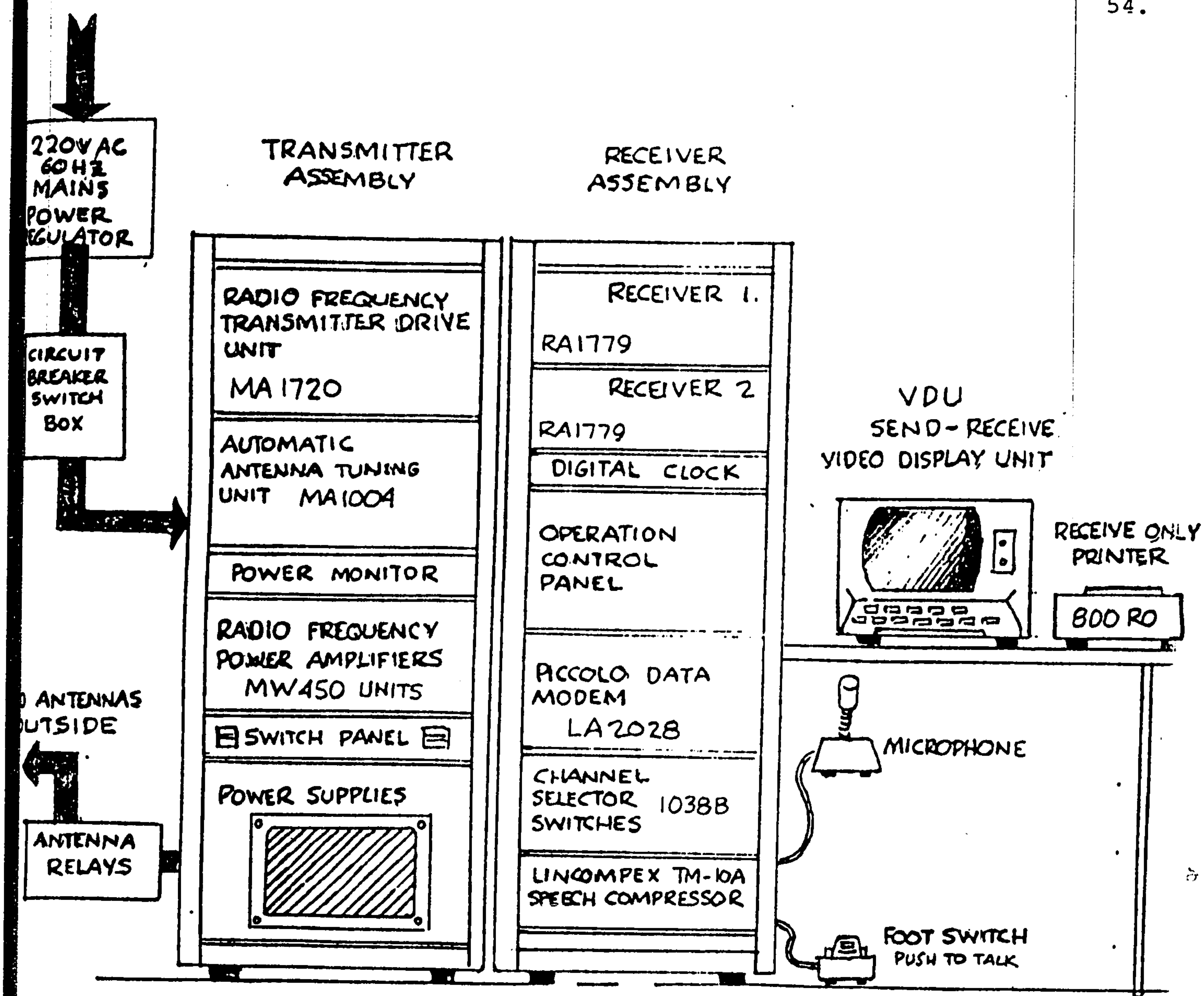


FIGURE 3-1

UP-GRADE OUTSTATION COMMUNICATIONS EQUIPMENT

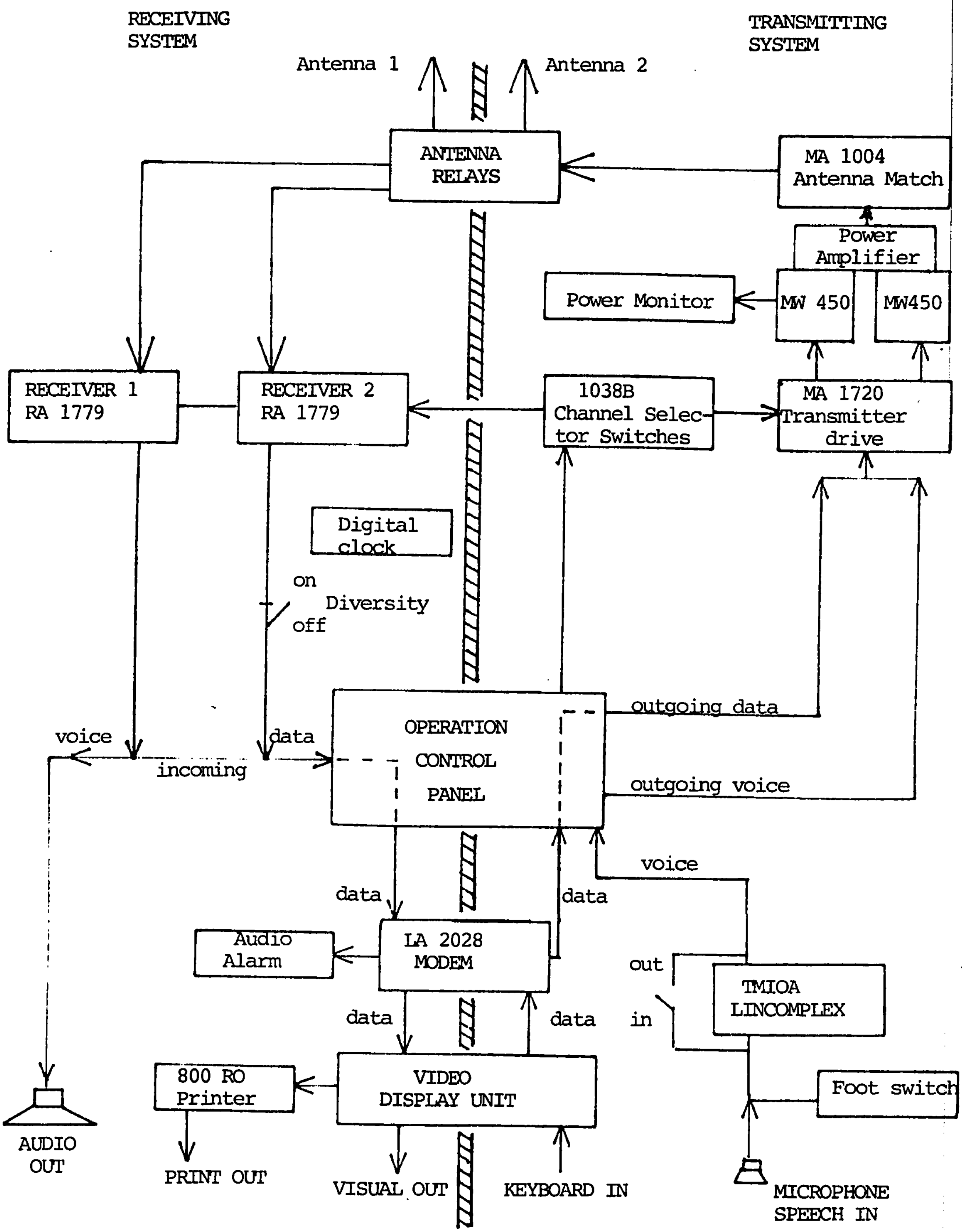


FIGURE 3-2
COMMUNICATIONS EQUIPMENT SCHEMATIC

COMMUNICATIONS EQUIPMENT HARDWARE

ITEM	MODEL	MANF	QTY
RADIO FREQUENCY TRANSMITTER DRIVE UNIT	MA1720	RACAL	22
AUTOMATIC ANTENNA TUNING UNIT	MA1004	RACAL	22
RADIO FREQUENCY POWER AMPLIFIERS	MW450	RACAL	22
POWER SUPPLIES	1784	RACAL	22
SYNTHESIZED LF/MF/HF COMMUNICATION RECEIVERS	RA1779	RACAL	44
32-TONE PICCOLO MODEM	LA2028	RACAL	22
CHANNEL SELECTOR SWITCHES	1038B	RACAL	22
LINCOMPEX SPEACH COMPRESSOR	TM-10A	RACAL	22
VOLTAGE STABLIZER	T52	RACAL	22
PRINTER	800/RO	RACAL	22
DESK MICROPHONE	AA653/C	RACAL	22
OPERATION CONTROL UNIT	SU183	RACAL	22
LINE SWITCH UNIT	MS139	RACAL	22
VDU DISPLAY UNIT	VITEL	RACAL	22
DIGITAL CLOCK	LA2028	RACAL	22

MANF = MANUFACTURE
QTY = QUANITY

FIGURE 3-2A

3.2 b) AUTOMATIC MESSAGE SWITCHING

What is proposed is a general purpose electronic message switch which includes extensive capabilities for the processing of meteorological data. It will be designed to satisfy the following objectives:

* Control of a communications network that uses low and high-speed WMO protocols, consisting of up to 50 lines in Baudot or ASCII code and operating in full or half duplex mode.

* Automatic routing of messages based on their WMO headers.

* On-line update of message routing parameters.

* A complete operator control language for the control and monitoring of system operation.

* Retention of all messages on an organized data base for a period of at least 24 hours.

* A restart capability with a minimum loss of data.

* Facilities for the detection and correction of errors in meteorological messages on the CRT's.

* Offline maintenance of the MSS data base. This data base provides for the definition of all messages handled by the MSS and definition of all system control procedures.

* CRT Retrieval of any message based on flexible search criteria.

* CRT inquiry of reports.

* Output of messages to a hand copy line printer.

* Retrieval of messages by remote teletypewriters.

* Retransmission of messages by remote teletypewriters.

* Automatic construction of meteorological bulletins on predefined schedules.

* Inquiry into a data base of station reports by any remote teletypewriter.

* Input of offline-prepared messages via magnetic tape.

* Offline programs to list all daily message traffic.

* Creation of plots showing surface observation.

The hardware required for the automatic message switch consists of dual digital computers with a configuration shown by Figure 3-3. Normally one processor will be used for reliability or other functions. The two processors will share a single data base through data storage disks which are accessible by either system. (8)

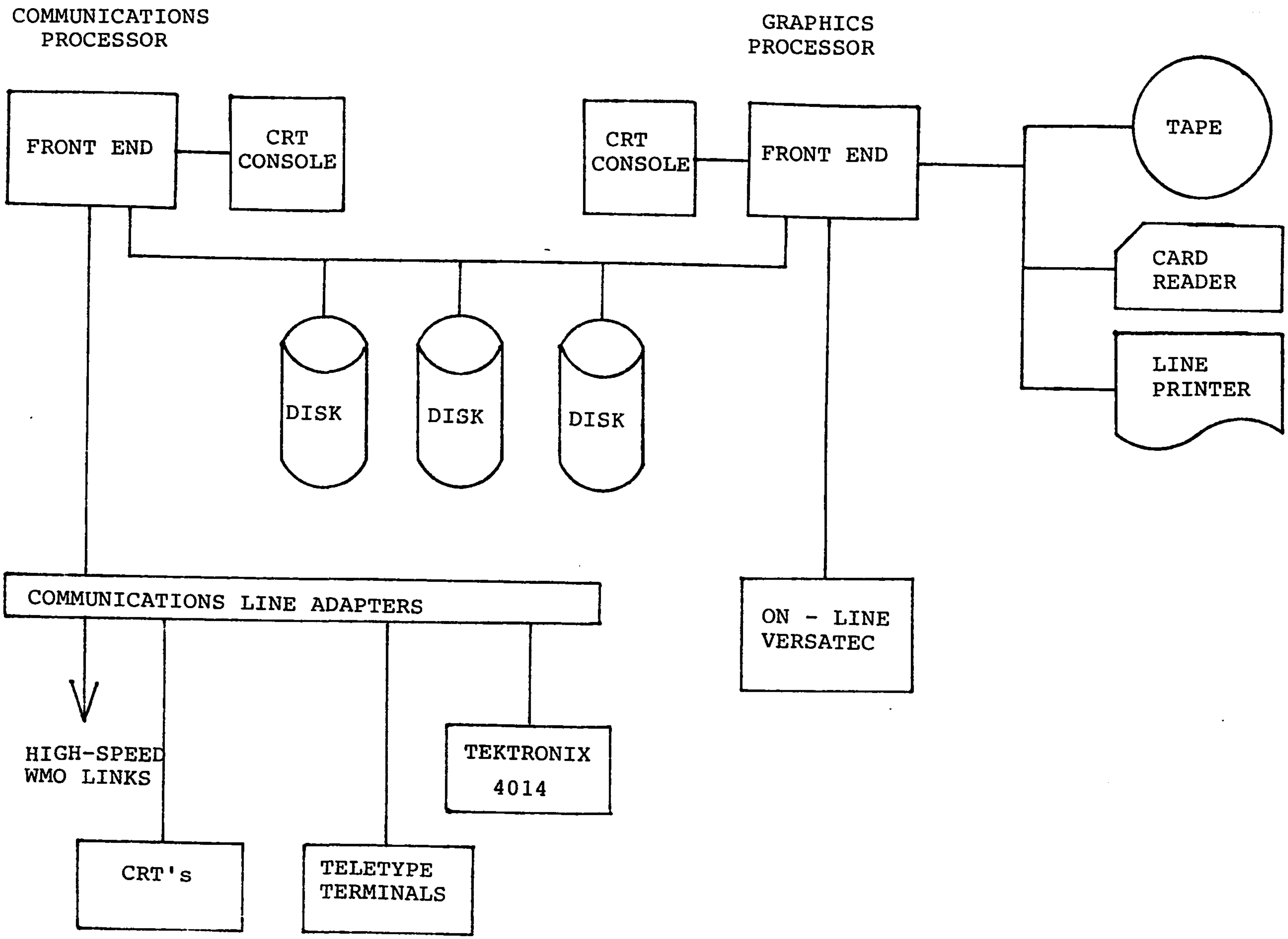


FIGURE 3-3

MESSAGE SWITCH HARDWARE CONFIGURATION

The message switch will consist of two main subsystems: (1) an offline data base maintenance subsystem, and (2) the online message switch. The offline maintenance subsystem is responsible for the creation or modification of tables residing on disk.

The online message switch controls the flow of messages into and out of the computers. All messages received from input circuits are stored on a message file and automatically transmitted to one or more output transmission lines. The MDT (Message Descriptor Table) is accessed for each message to determine where that message is to be sent. (8)

A message may also be routed to magnetic tape for long-term storage or batch processing. Additionally, some messages indexed by the Station Index or Decoded Data Base can be retrieved for use in plots by the forecasters. (8)

Each message which enters the system will be edited according to format rules specified in the MDT. If a message is found to have format errors, it will be routed to the error processing queue. From there it can be redisplayed for operator manual correction on the CRT. Once corrected, it will be reentered into the MSS for normal routing. Meteorological data errors are not checked by the MSS. (8)

On a schedule determined by a BCT (Bulletin Construction Table), the MSS will construct bulletins from reports stored on the Cyclic Message File. These are then entered into the system for normal routing. (8)

Each remote terminal on the communications system has the ability to send in messages requesting the retransmission of previously sent messages. Each terminal can also enter inquiry messages requesting reports or messages on the data base. The local operator has a number of control commands, entered through a CRT, which allow him to monitor and control the functions of the message switch. Messages can be entered, retrieved, retransmitted, corrected, and changed through the CRT's. (8)

A message that enters the system may be routed to one or more destinations. A destination can be an output line, a magnetic tape, a processing program, an error processor, a holding disk queue, or any of a variety of special-purpose destinations as defined by the MSS user. The method of routing in the message switch will be quite flexible but it will also be somewhat complicated. The ultimate routing decision for a particular message will be a function of three factors:

* The message routine specified in the Message Descriptor Table (MDT).
* Queue-destination relationships.
* The validity of the message contents, and the contents of the routing tables.

A schematic summary of the proposed routing procedure is illustrated in Figure 3-4. As is shown by this figure,each incoming message (A) will be placed on the input queue (F) corresponding to its input line. Associated with each input line is a routing table (R) which can contain specific output destinations for each message received on that circuit. (8)

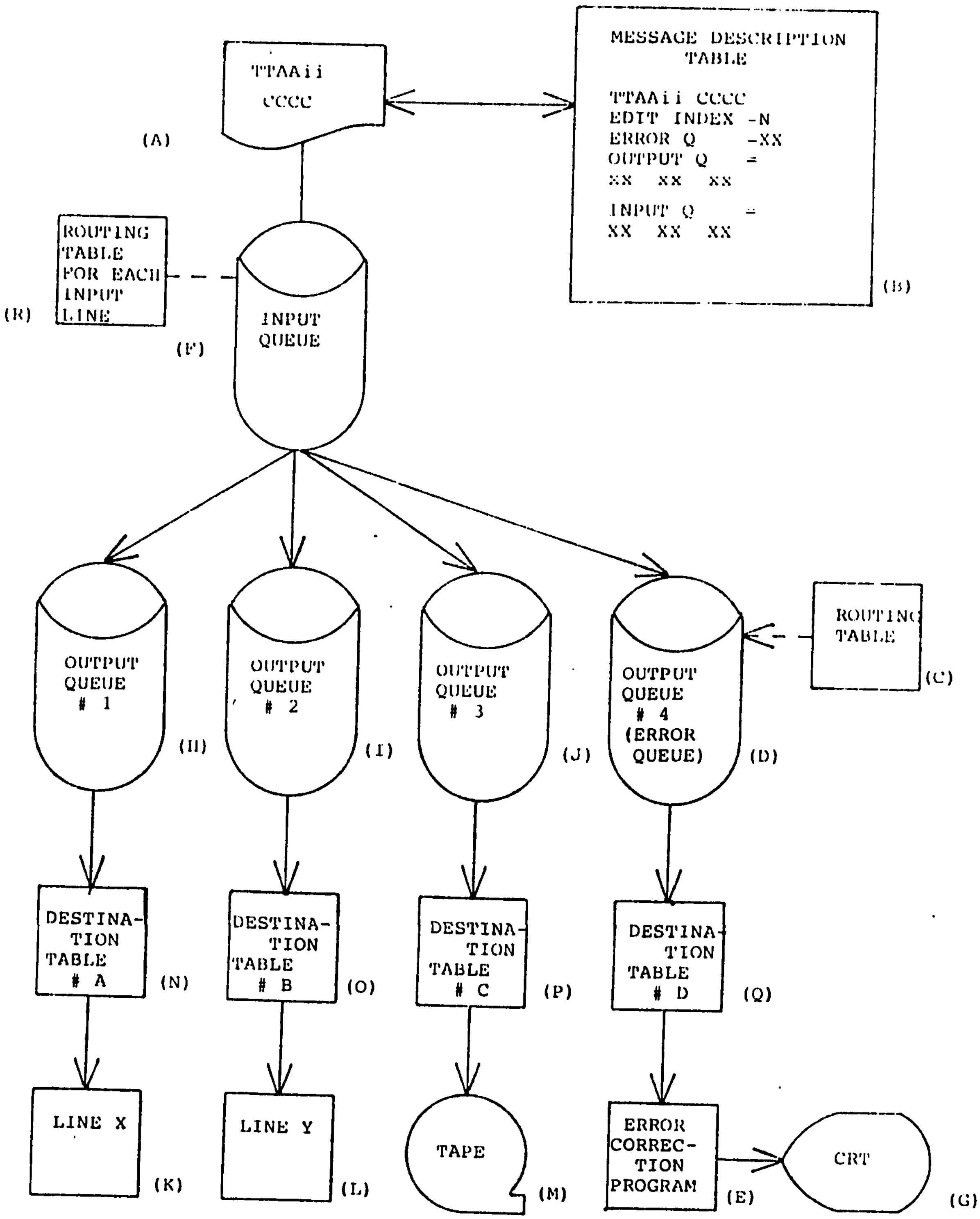


FIGURE 3-4
SCHEMATIC OF MSS ROUTING METHOD

The system also looks up the MDT (Message Descriptor Table) entry corresponding to the TTAAii/CCCC of the input message. If no matching MDT entry is found (invalid TTAAii/CCCC), the system uses routing table 0 (C) to determine into which error queue (D) this unknown message shall be placed. The MDT contains a list of valid input sources for each message type. If the actual input source does not match one of these values, the message will be ignored by the system. (8)

If a known message type contains format errors, it will be routed to the error queue specified in the MDT (D). It will be subsequently processed by the error correction program (E) and displayed on the CRT (G). (8)

Contained within the MDT will be references to one or more output queues. Each valid message is then placed in each specified output queue. A queue is simply a holding area (on disk) wherein a message is saved until it can be transferred to its destination. There are several types of destinations within the message switch. Most destinations are output lines, but there are also other destinations such as the output tape and several processing programs. Permanently associated with each destination is a Destination Table. The relationship between destinations and queues can be changed by the operator. It will be possible to have any number of Output Queues associated with each Destination Table. Messages are sent to the destination in a priority determined by the order in which the Output Queues are associated with their Destination Tables. All messages will be extracted from the first queue before any messages are extracted from the second queue (and so forth). (8)

The message switch will contain a special bulletin processor module which automatically combines incoming reports into outgoing bulletins on a specified schedule. The Bulletin Composition Table (BCT) will define the contents of each bulletin created and the time and day when it is to be constructed. The input reports are retained on the Cyclic File until it is time to construct the output bulletin. At that time, specific reports are retrieved from the Cyclic file and combined together into a single message (or bulletin). The bulletin is then routed to various destinations. (8)

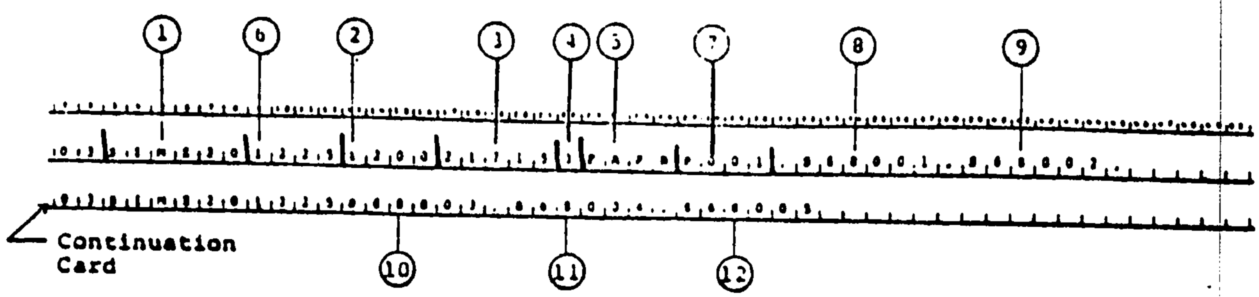
The Bulletin Composition Table will be created from a card image file. Each outgoing bulletin is described by a set of one or more cards. A bulletin is structured into three parts:

* Start line and abbreviated header line (lines 1 and 2).
* Special message line (line 3)
* Report lines

Figure 3-5 provides a sample bulletin, showing the basic components. The initial two lines of the bulletin are completely defined by the first BCD input card. (9)

The creation of bulletin text is controlled by parameters known as "bulletin elements." These are coded starting in column 27 of the first card and may be continued onto continuation cards. A "P" (special group) bulletin element causes the construction of the third line containing the special message groups. The reports which are included in the main body of the bulletin are identified by one or more "S" (station) elements or "Q" (queue) elements. (9)

A. Sample Input Bulletin Control Cards:



B. Sample Bulletin (Constructed According to Input Card Specifications):

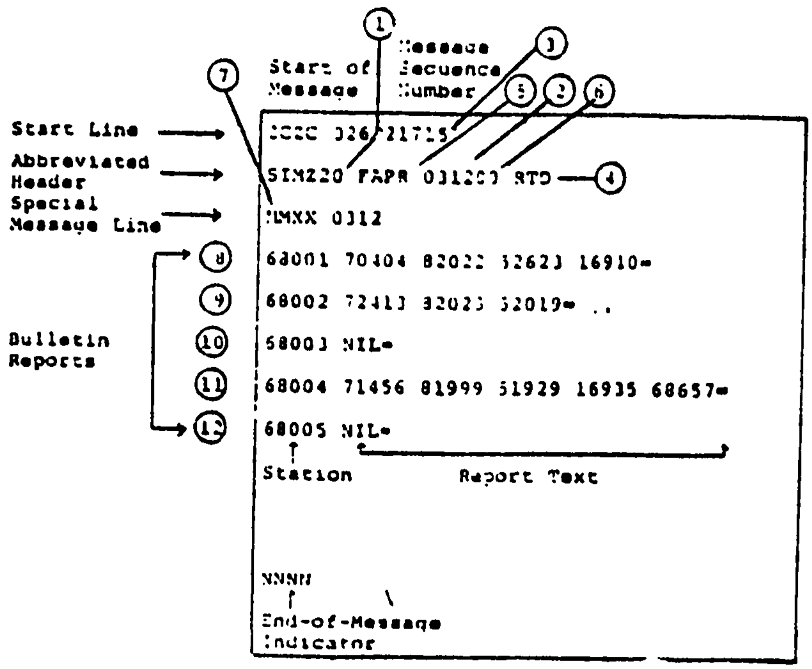


FIGURE 3-5
SAMPLE BULLETIN STRUCTURE

The following list defines all input parameters to be contained on the first BCT card for each bulletin report group. Columns 27-71 of this card are reserved for bulletin elements. Bulletin elements may extend to but not beyond the 71st column of the BCT card. (9)

The interrationship between the Bulletin Composition Table (BCT) and the actual bulletin structure is shown in part A and B, respectively. The following list identifies the bulletin fields by their WMO codes. Refer to the following list for more detailed descriptions of these bulletin fields.

1. TTAAii - bulletin identifier
2. CCgg - observation hour
3. CLLLL - bulletin catalog number
4. X - bulletin modifier code
5. CCCC - station of bulletin origin
6. Time of bulletin construction
7. P001 - special group element

8-12. Station elements on the input cards correspond to station reports in the bulletin output. Note that only 3 of the 5 station elements had reports, the remaining 2 being marked NIL for no report. (9)

In some cases, many elements may be required to define a particular bulletin. If more elements exist than can fit into the first card, then one or more continuation cards will be used to accommodate the remaining elements. The parameters in Columns 1-12 of each continuation card must be identified to those specified on the first BCT card of the set. The bulletin element information within each continuation card must always begin in column 13. (9)

Care must be taken in the scheduling of bulletins such that not too many are scheduled simultaneously. Although there is no danger of overloading the system, if too many bulletins are created at once, they will simply sit in the output queues awaiting transmission.

3.2 c) MESSAGE DECODER

The decoder will reside in the Automatic Data Processor (ADP) which is a component of the Main Computer Software (MCS). The MCS will be run on a **main frame** computer system. Decoder is a batch program which means that the computer itself will execute the program without continued operator intervention. The operator will only need to enter a few commands at a terminal to initiate the program and then will be free to use the terminal for other activities.

Decoder is used to process data from two sources: current incoming weather information received by the 735 and previously collected data archived on tape. Incoming data received by the MSS is stored in cyclic files on disk for transfer to the main frame.Previously collected weather data will be archived on tape and stored in the center's tape library. These tapes will be catalogued by year and data type.

Decoder will be made up of a number of other programs. The first of these, the CYCRDO (Cyclic Read) program, will read the tape and translates its stored data into text that is readable on a CRT screen. It also sorts the tape's bulletin by bulletin type and stores them in a series of special files called Collation Files. Once the tape is read in and its contents sorted and translated into the Collation Files on disk, the actual decoding will begin. This is a lengthy process making heavy use of the system. The actual decoding will be done by BTCHDEC (Batch Decode) program which calls a series of sub-programs called Decode Programs. There is one Decode Program for each Collation File, so that the individuality of the various bulletins can be dealt with effectively. (10)

The order in which the Decode Programs are called corresponds to the order of importance attached to the bulletin type stored in their parallel Collation Files. This is so that the most useful bulletin will receive first consideration as a buffer against possible time on operational problems which could interrupt the decoding before all the files have been processed. Synoptic data will be decoded first since it is considered the most useful data for forecasting. (10)

Each Decode Program works through its related Collation File bulletin by bulletin and message by message, first decoding them, next verifies the quality of their contents, and then deciding on their disposition by invoking special Add Routines. These Add Routines are used to send decoded, acceptable data to the Objective Analysis data base, the Climate Data Base, on to the Reject File in case of suspect data. The DECODER is divided into those phases: decoding, verification, and disposition. (10)

A Decode Program will look through its Collation File until it recognizes a bulletin header. After reading through the header, it will then obtain the first undecoded data group of the first message by reading the bulletin up to the first blank. This will be all on part of the message's identification depending on the bulletin type. In most cases, it will be the complete identification and will consist of a block number and an international station number. It then continues with each group until all individual elements are decoded. (10)

Any failure to recognize a data group will cause the message to be flagged and sent to a Reject File. The program will make an attempt to deal with common errors often encountered in meteorological messages. It throws out garbage characters and extraneous text. A list of the decoded fields will be sent to an array called List Fields, and the actual values of those fields will be sent to another array called List Values and Flags. These series of steps will be repeated until the end of the message is reached. When the decoding phase is finished, the arrays are passed to the Verification Routines. (10)

The Verification Routine looks for data that is outside certain ranges or inconsistent data. The routine continues until it finds any such error and sends a copy of the complete message to the Reject File. This copy will be flagged with a single letter code indicating the nature of the error. The Verification Routine will perform the following meteorological checks:

For Synoptic Bulletins:

a) If wind speed is greater than 2.5 m/s, then a wind direction between 010 and 360 must be reported.

b) If visibility is greater than 2.5 km., the code for present weather must be less than 4.

c) Surface pressure reported must be between 800 and 1300 mb.

d) The dew point must be less than or equal to the air temperature. Temperature must be between -60° and 70°C.

e) The total cloud amount must be greater or equal to the low cloud amount. The height of low clouds must be less than that of middle clouds which must be less than that of high clouds.

f) Station pressure reported must be between 700 and 1300 mb.

For Upper Air Bulletin:

If the pressure is being reported, it must decrease with height. If the height is being reported , it must increase.

For METAR Bulletins:

All the same checks apply that are used for synoptic data plus the altimeter setting must be between 700 and 1300 mb.

For SHIP Bulletins:

a) Synoptic tests one applied, plus

b) the height of a wave cannot be greater than 50 m. The direction of the wave cannot be greater than 360 degrees.

c) Sea temperature must be between -10 and 50 degrees C. (10)

After a message has been decoded and verified or pronounced undecodable, an interface Add Routine will be called so that the message can be sent to the Objective Analysis data base, to the Climate Data Base or to the Reject File for editing. There is a special Add Routine for each bulletin type.

There will be interface routines which communicate between one Main Computer Software Component and another. (10)

The geographical origin of a message determines where it is sent. All data within the range of 40 degrees south and 60 degrees north for all longitudes will be sent to the Objective Analysis data base. All data from the area immediately around Saudi Arabia, from 10 degrees south to 60 degrees north and from 15 degrees west to 85 degrees east will be sent to the Climate Data Base.

The Reject File contains the messages the DECODER found unidentifiable and copies of the messages it found undecodable or unverifiable. Since DECODER has already transformed these messages into text files, they can be displayed on a CRT and corrected by an operator using an edit program. Then they are resubmitted to DECODER to see if they are now decodable and/or free of errors. If they are not, they are sent back to the Reject File and the process will be repeated until success is achieved or the effort is abandoned. (10)

3.2 d) - OBJECTIVE ANALYSIS FOR WEATHER FORECASTING ASSISTANCE

"Meteorological objective analysis" can be defined as an attempt to depict a continuous three-dimensional atmosphere on a discrete, regular grid lattice. "Objective" implies that, within limits, all meteorological observations are treated in the same prescribed manner in an attempt to get the discrete regular grid lattice to reflect an integrated picture of the observed values and their distribution. This is contrasted to a "subjective" analysis in which a trained meteorologist draws isolines of a particular parameter integrating each available observation on its own merits along with an educated guess of how the structure should look.

In meteorological analysis, one piece of information that should not be ignored is the most recent past analysis or, if available, a good forecast valid at the current analysis time. A person doing a hand analysis usually uses such information. In particular, the analyst needs an estimate of the position of highs and lows (curvature) and of the areas of strong and weak pressure gradients. In referring to the past analysis or forecast, the person usually is looking not so much for absolute magnitudes as for the shape of the field. When drawing the new analysis, a first attempt is made to fit the shapes in the past field to the new data. If conflict occurs, the new data takes precedence unless the analyst suspects that the data is in error. In regions where data is routinely sparse, many conflicts need to be resolved because of the accumulation of errors.

The best objective analysis scheme is probably one that follows the same rules that a person follows. If such objective techniques can be worked out, the machine may do the job in a more consistent manner than a person a generally able to do.

The basic goal of the scalar pattern conservation analysis technique is to fit the following information to varying degrees: the new data; the most recent past analysis of forecast value (the first guess); the gradients of the first guess in eight directions from each grid point; and the curvature of the first guess. The degree of fit desired for each piece of information is specified by an array of weights.

The desired fit is obtained by minimizing the sum of the deviations of the various characteristics of the analysis from their values in the first guess. The minimization is performed by an elementary application of the calculus of variations.

The gradient and curvature terms represent information that is spread through space. In a surface analysis, there are sometimes natural obstacles (mountain ridges, coastlines, etc.) beyond which an analyst would not allow a new observation to influence the analysis. This kind of constraint can be simulated in the objective analysis by reducing the weights of the gradients and mathematical Laplacian operator along the demarcation zone.

An analysis cycle consists of three basic steps:

1. Assemble the data to grid points
2. Solve the minimization equation
3. Re-evaluate the weight of each report

In order to adequately evaluate the weight of each report, at least two cycles are required. It is desirable to include at least one additional cycle to allow initially suppressed data to enter the analysis with a high weight if supporting data some distance away causes the analysis to conform more closely to the report after the second cycle.

1. <u>Analysis Grids</u>

In an attempt to depict the continuous three-dimensional atmosphere, meteorological objective analysis uses a discrete regular grid lattice. This requires that levels in the atmosphere be represented by two-dimensional horizontal grid lattices.

In the horizontal, the atmosphere is composed of a complex spectrum of eddy type motions. These flows range from turbulent eddies with a horizontal scale of a few centimeters to the mean zonal wind with a scale of tens of thousands of kilometers. The grid resolution must be chosen with care to depict the desired scales without creating too much computational effort. The use of the analysis also has bearing on the resolution. Analyses which are used for qualitative applications (i.e. briefings, etc.) do not need be as sophisticated as those that are used for specifying initial conditions for a prediction model.

Special conditions prevail in the tropical latitudes. Storms have smaller spatial scales (tropical storms have a horizontal scale of hundreds of kilometers, compared to mid-latitude synoptic scale cyclones with a scale of thousands of kilometers). Horizontal pressure gradients in the tropics are considerably weaker than in the mid-latitude westerlies.

Diurnal pressure variations are often larger than synoptic changes. The most apparent difference when doing analysis is the sometimes extremely poor observational data volume and distribution.

A practical operational approach to grid selection is to define a coarse-mesh grid to depict the large-scale pattern of the atmosphere and an inbedded small-area fine-mesh grid to allow finer resolution when justified by display or data needs.

2. <u>Analysis Execution</u>

An objective analysis system requires the execution of a number of programs in a prescribed sequence. This sequence is executed every twelve hours to introduce the new meteorological observations which are taken in the upper atmosphere (UA) on a twelve-hourly cycle. Surface observations are taken more often and so several surface analyses may be run during each 12 hour period.

The execution of the various programs are distributed among various computer jobs which are identified with computer control cards. The task is broken into smaller jobs for many reasons:

1. Various parts of the analysis have to be done at different times depending upon data receipt time.
2. If hardware or software problems cause a job to fail, only that small portion need be recomputed.
3. It allows built-in holds in the analysis when meteorologist input is required such as reviewing preliminary analyses or the preparation of additional input data. (11)

Each program execution transfers its output to other programs within the same job or in other jobs by writing its output into a file on disc in the form of records. A record depicting a meteorological parameter is composed of an array of numbers representing the parameter value at each of the grid lattice points plus a few identification words. The collection of control cards and data cards comprising a job will reside as files accessible for operator execution at the appropriate time or for automatic execution. (11)

Meteorological analysis is a time-critical process. The products should be available to the meteorologist before the product becomes obsolete due to passage of time.

This means that the objective analysis programs must execute as quickly as possible after the data are made available. The execution time is limited by the capabilities of the hardware, the design of the programs, and to a small extent the volume of data.

3. <u>Analysis Control and Tuning</u>

Since a reasonable first guess is a necessary requirement for meteorological analysis, special procedures must be included to generate the first guess requirement.

The most obvious is a procedure for starting up the analysis sequence for the first time. In this case one has current observations but no first guess since a previous analysis sequence has not been run. The procedure to get the sequence started is to use historical climatological data fields of the parameter being analysed as a best approximation to a first guess field. If adequate observational data is available, the observations soon define the current state of the atmosphere.

The historical climatological fields also have another purpose. Even with the analysis system cycling routinely, data are obtained from the tropics and oceans intermittently or not at all. In this case of no observational data, the analysis fields are gradually reverted to climatology. This helps remove synoptic features which were defined data in the past and which persist in the absence of data to redefine the current situation.

Synoptic systems, especially in the mid-latitude, are migratory and their motion is usually obtained in the first guess fields by a forecast model. This will be accomplished by generating steering current fields from appropriate analysis fields and advecting the first guess fields for the appropriate time period.

Meteorological data are not always correct due to incorrect calibration or workup, transmission errors, etc. Objective analysis programs attempt to reject these bad observations but sometimes their incorrect influence affects the analysis fields. The method used to allow meteorologist intervention in quality control is through a "bogusing" procedure. On crucial parameters a preliminary analysis is performed to see the effect of the available data. Trained meteorologists using additional tools such as satellite pictures are able to make changes in the final analysis by forcing rejected observations to be accepted, reject unwanted accepted observations or enter "pseudo" observations of a desired value at desired locations (bogus data).

Individual meteorologists, given the same observations, will interpret them differently in producing an analysis. In objective analysis programs the same will be true. There are numerous discretionary procedures and tuning constants that can be introduced.

4. Software Description

a) Grids/Fields/Data Formats

1. Grids

A course mercator grid will be chosen for the Saudi OAS System since it has the following advantageous characteristics:

a. They cover the latitudional extremes of interest to Saudi meteorological applications.

b. They encircle the earth allowing the generation of reasonable first guess fields.

c. The grid resolution allows the required software to fit the available machine resources and to run in an operationally acceptable time.

The fine-mesh grid will be similar to that being used in Saudi Arabia for manual analyses.

The mercator projection true at 22½° latitude is defined by the equation:

$$X = \operatorname{Ln}\left(\tan\left((90-y)/2\right)\right)\frac{Rm}{d}\ \cos 22\tfrac{1}{2}°$$

where

X= latitude index

y= latitude

Rm= mean earth radius= 6371.229 km.

d= grid mesh distance at 22½°

The course mesh grid which will be used is a global band grid which extends from 41.0016S to 59.7952N and encircles the earth. (11)

The grid resolution is $2\frac{1}{2}°$ at the equator giving a value of "d" at $22\frac{1}{2}°$ of 257 km. This grid therefore is comprised of 49 gridpoints in the latitude direction and 145 gridpoints in the longitude direction. This results in a total of 7105 (49 x 145) points at which the value of a parameter must be specified.

The small area fine-mesh grid will extend over the Saudi Arabia area from 15W to 85E and from 9.9559S to 59.7952N. The grid resolution is $1\frac{1}{4}°$ at the equator or half the mesh size of the full global band. This will make the value of "d" be 128.5 km. Therefore, there will be 69 latitude gridpoints and 81 longitude gridpoints for a total of 5609 (69 x 81) total gridpoints. (11)

2. Fields/Data Formats

   a. Naming Conventions - System Label

      Any data base management system must have some algorithm that names each different type of data that is to be stored. The convention selected for the objective analysis system includes a combination of three characters specifying the level/type of the data, four characters spcifying data time group (DTG) which applies to the data, and one character specifying the project/ grid or area.

The record name will consist of eight display code characters as follows:

YXXMMDHZ

where Y = basic field type or altitude code
XX = element or parameter code
MMDH = date time code
Z = projection, grid or area code

Tables 3-7 through 3-9 show the various identifiers chosen. (11)

b. Field Idents

In objective analysis, one must differentiate between fields and data. Fields are the desired end product of objective analysis or prediction. These fields are two dimensional arrays of numbers whose numerical value represent the value of a particular parameter, an earth location, and level. The earth location which corresponds to a particular gridpoint is specified once the type of map projections, resolution and area to be mapped are specified. These fields are stored in the file GRID as records with a unique name. Data refers to raw or partially processed observational data. (11)

Included in each field record along with the grid values will be 20 words which contain values descriptive of the field.

BASIC FIELD LEVEL CODE

ATMOSPHERIC DATA	
Display Code Character	Type
A	Surface
C	1000 mb
D	950 mb
E	900 mb
F	850 mb
G	700 mb
H	400 mb
I	400 mb
J	300 mb
K	250 mb
L	200 mb
M	150 mb
N	100 mb
O	50 mb
P	30 mb
Oceanographic Data	
W	Surface

TABLE 3-7

ELEMENT OR PARAMETER CODE

DISPLAY CODE	ELEMENT
ATMOSPHERIC DATA	
01	Height
10	Temperature
20	U Wind Component
21	V Wind Component
22	Isotach
23	Wind Direction
24	Wind Barbs (Combined)
31	Dew Point
50	Relative Vorticity
51	Divergence
52	Analysis Divergence
60	SR = Residual
61	SL = Large Scale Disturbance
62	SD = Small Scale Disturbance
63	SV = Planetary Vortex
Oceanographic Data	
01	Temperature

TABLE 3-8

DATE TIME CODE (MMDH)

MM = Month

D = Code for observation day

H = Code for hour of observation

This date time code was designed to contain only alpha-numeric characters (no imbedded blanks or special characters were allowed). The range of permitted characters in display code is from $(01)_8$ = A to $(44)_8$ = 9. Thus the number system selected for calculation of MM, H, and D was base (Radix) 36 with the following order:

RADIX 36 NUMBER	DISPLAY CODE EQUIVALENT	DISPLAY CODE CHARACTER IN SYSTEM LABEL	RADIX 36 NUMBER	DISPLAY CODE EQUIVALENT	DISPLAY CODE CHARACTER IN SYSTEM LABEL
00	01	A	18	23	S
01	02	B	19	24	T
02	03	C	20	25	U
03	04	D	21	26	V
04	05	E	22	27	W
05	06	F	23	30	X
06	07	G	24	31	Y
07	10	H	25	32	Z
08	11	I	26	33	0
09	12	J	27	34	1
10	13	K	28	35	2
11	14	L	29	36	3
12	15	M	30	37	4
13	16	N	31	40	5
14	17	O	32	41	6
15	20	P	33	42	7
16	21	Q	34	43	8
17	22	R	35	44	9

TABLE 3-9

c. Data Format

The observational data will be automatically decoded from meteorological messages and stored in records whose first three characters reflect the type of data. In order to minimize the number of words required to store the data, multiple parameters will be packed in a single word in a format which sets aside enough bits to represent the largest anticipated value.(11)

The record names, length and data intervals are described in Table 3-10.(11)

ELEMENT NAME CODES FOR OBSERVATIONAL DATA

NAME	TYPE	RECORD SWITCH	WORDS PER REPORT	DATA INTERVAL
SLC	Surface Land	4800	3	3 hourly
SSC	Ship	4800	4	3 hourly
RMC	Raob Mandatory	4500	18	6 hourly
RMO	Checked Raob Mandatory	4500	18	6 hourly
RSC	Raob Signifi- cant	4500	15	6 hourly
PIC	Pibals	4600	20	6 hourly
ARC	Airep	4800	2	12 hourly -6 to+12
UTC	SIRS	4500	18	12 hourly (00 to+12)
UTO	Checked SIRS	4500	18	12 hourly (00 to+12)
UDC	Cloud Vector Winds	1000	1	12 hourly (00 to+12)
SAC	Hourly	4800	6	6 hourly

TABLE 3-10

SYSTEMS FOR ANALYSIS VERIFICATION AND INTERACTIVE DISPLAY (SAVID)

SAVID is an analysis verification and interactive display program. It has been developed to verify and enhance the quality of the analysis products generated by the Objective Analysis System. Those products are a series of gridded fields for parameters at various levels of the atmosphere which were interpolated from primary or raw observational data. SAVID also overplots on the analysis the raw data used by OAS to generate the grids. The data plots are then used in the quality evaluation of all maps produced in the process. (12)

The interactive display portion of SAVID will provide the operator with the ability to display maps on the cathode ray tube (CRT) monitor, to store them on tape, to plot in hardcopy, and to interact with the computer when the displayed map is judged in need of modification. The interaction involves rejecting or accepting the overlaid data values on introducing additional values when such alteractions are necessary to improve the quality of the map. Corrections are usually made in areas with little or no available data that cause unreasonable distortions in the contours. (12)

The purpose of SAVID is to provide accurate, useable contour maps that visually show a variety of weather information. These maps can have contours of temperature, dew point, wind speed and direction, height of pressure surfaces, and other parameters at a variety of atmospheric levels. (12)

The quality and usefulness of the maps is dependent on the original data used to generate them. Missing reports or incorrect reports will cause distortion in the contours, which detracts from the map's value to the forecaster. SAVID deals directly with data problems by allowing the forecaster to see where the errors occur, and gives him the capability to make modifications to the original data to correct the analysis. (12)

SAVID will be an integrated part of the Main Computer Software because the data that it needs for operation must pass through other components before it is useable. Station reports received by the Message Switch are passed to the Automatic Data Processor. The decoded data is then stored in the Climate Data Base and is accessible by SAVID. The amount of data will vary depending on external conditions. For this system at least 70% of the synoptic and upper air data that is normally available on the Global Telecommunication System must be in the CDB for the OAS to produce an acceptable analysis that is not based mostly on climatology. (12)

The SAVID program will provide the capability to display the gridded fields produced by OAS and the means to monitor those fields. In this case monitoring means visual inspection of the analysis by an experienced meteorologist and the use of this subjective judgement to improve it. Monitoring is very important, especially over data- sparce areas. A grid-point value is an interpolation of coincident and surrounding raw values. The quality of these values determines the degree which the derived grid-point reflects reality. (12)

Areas of poor or little data can produce exaggerations in the gridded field. Therefore, the gridded fields must be monitored and corrected. In practice the surface and 300 mb. levels are routinely monitored. If significant corrections are made, then the OAS must rerun to integrate those changes vertically to other atmospheric levels.

The first phase of SAVID will begin on the main computer CRT terminal. SAVID will offer the forecaster options of parameters and levels that he wants displayed, as well as the choice of the map projection that will serve as the background. SAVID will then access the CDB and retrieve the requested gridded fields. Next it will contour them, overplot certain of the raw data values used to create those fields, and then overlays all of these on the constructed map. The amount of plotted data is determined by the selection of map scale. Only 10 to 15 percent will appear on a hemispheric map since the program will not superimpose data, but 100 percent will be seen on an expanded sectional map. (12)

During the second phase of SAVID, the forecaster will remain logged on to the terminal, and also logs on to the Objective Analysis Graphic Output Terminal. The map just prepared appears on the graphics terminal and can be changed if necessary. Raw values which were outside the OAS tolerance limits will be displayed with flags. There will be three ways to make connections. First will be to force the OAS to accept a raw value that it had previously rejected. The second is to make OAS ignore a value that it had accepted. The third is to insert a value when none existed before. The fictitious value is called a bogus report. (12)

In practice SAVID will consist of performing a sequence of steps for each value that is changed. This sequence is called a SAVID Pass. The location cursor on the graphics terminal will be aligned with the value to be accepted or rejected or the location where a bogus value is to be added. An entry is made at the terminal to indicate which of these actions will occur. The exact latitude and longitude of the selected point are shown. If a value already there is being rejected or accepted that value will also be provided for confirmation. Otherwise, a bogus value will be entered. Finally, SAVID makes sure that the action taken is to be saved and will inquire if there is to be another pass. If the program continues the same sequence of events is repeated. All the actions taken by SAVID are stored in the CDB. The effect will not be visible until OAS generates a new set of fields incorporating the modifications. The plot files created during a SAVID session can be sent to tape for storage, sent to tape for transfer to automatic plotters for hardcopy plotting, or deleted. Shown in Appendix B are examples of computer plotted surface and upper air charts using SAVID. (12)

3.2 e) CLIMATE DATA BASE

The Climate Data Base (CDB) is an integral part of the Main Computer Software. The CDB is the central core of the MCS and provides a functional and historical link between all the MCS components. Its main purposes are:

a) To maintain a historical and realtime data base for meteorological purposes.

b) To provide easy access to the data base through interactive terminals.

c) To store the data in forms usable by the OAS, ADP and the programs associated with the CDB itself.

In the strict sense of being a data base, the CDB consists of the data that resides readily available on disk in predefined formats. However, in the operational context of the MCS, a reference to the CDB can also imply the data that is archived separately on tape and only a "read" away from disk.

In the broader sense, the CDB consists of both the data base and the various related programs, and it is in this sense that the CDB will be discussed. (13,18)

The Data Base

Global weather bulletins come into the MCS from magnetic tape archives (historical) and from tapes brought over from the MSS (near real-time). They are then decoded by the ADP and sent on to the CDB.

The CDB divides this incoming data into two categories: (1) global data destined for the OAS that is being temporarily stored, and (2) local data that will be part of the data base itself. The first group will be stored in OAS Files in a special format, the second in CDB Text Files in a variety of formats. As these two filenames imply, the CDB Text Files, being text files, can be displayed on the screen or printed out in hard-copy while the OAS files cannot. (13,19)

In the case of CDB Text files, incoming bulletins will be further divided into 12 basic subcategories or Data Types listed in Table 3-11. The Data Type becomes part of the filename of the Text File, and so becomes a factor in the storage and retrieval of the file. For this reason, it must be explicitly referred to during the operation of many of the programs associated with the CDB as well as while using the ADP's Reject File. The CDB data types are given in Table 3-11. (13)

The CDB Text Files where the various Data Types are stored will be formatted so as to make them as easily readable as practical. Since mandatory and significant versions of a Data Type may each require a different format, the 12 Data Types are actually expressed in 14 formats. (13)

This means that when a synoptic observation is accessed it will be displayed as shown in Figure 3-6.

CLIMATE DATA TYPES

TYPE	BULLETINS CONTAINED IN DATA TYPE
SLC	Land and Auto Synoptic
SSC	Ship and Auto Ship Synoptic
RMC	Raob and Shipboard Raob (Mandatory)
RSC	Raob and Shipboard Raob (Significant)
PIC	Pibal (Mandatory and Significant)
SAC	METAR
ARC	AIREP
UTC	Satellite Soundings
UDC	Satellite Winds
CLS	CLIMAT
CLU	CLIMAT TEMP
A17	Auto 17-Station Air Quality and Marine

TABLE 3-11

To aid the task of reading such an observation, a set of templates has been provided so that the different data groups within the observation can be understood. At a glance, the form of the template should immediately correspond with the form of the displayed observation, character and space by space. This can be illustrated by comparing the template for the SLC Data Type, shown in Figure 3-6,with an actual observation reproduced in Figure 3-7. (13)

Not all of the data that comes into the MCS will be useful to the Center on a long-term basis nor can it all be easily stored and maintained on the system. Disk space will be limited and needed for immediate, ongoing operation of the Center. The disk cannot be overloaded with unneeded or old data. There is also a practical limit to the number of tapes which a tape library should contain, and there is no point in storing data on tapes, if that data is not likely to be used.

During the normal operation of the Center, the OAS will be run shortly after ADP data arrives in the CDB. For this reason, the CDB will delete all OAS Files that are over 24 hours old. By that time, the Files should have been used, and room is needed for incoming, new data. No attempt will be made to archive OAS Files. (The products of SAVID, however, can always be stored in hard copy form or on a separate tape).

```
40356 0100 E 8  50  6 9.0  5 6 1027.2   4 8 5 4 / /  2 5  .2////// 97 ////
           4 2 7  300 4 6  450 8 6   900 / / /////
```

FIGURE 3-6
A SYNPOTIC OBSERVATION

```
IIIII DAHR F N DDD SSS VVVV WW W SLPRES TTT N C H C C TDT J PPP STPRES RR SSSS
          JJ N C HHHHH N C HHHHH N C HHHHH N C HHHHH
```

FIGURE 3-7
THE SLC TEMPLATE

On the other hand, the CDB Text Files of data local to Saudi Arabia are intended to take up residence in the CDB, and some of them will eventually be archived on tape. The criteria ruling their storage are more complex than those covering the OAS data.

Initially, all land and ship data of the types listed in Table 3-11 that falls within the area of 10 degrees south to 60 degrees north and 15 degrees west to 80 degrees east is to be sent to the CDB to be stored on disk as CDB Text Files. This area includes Saudi Arabia and its contiguous countries and corresponds to the Zoom projection of the SAVID program. (13)

After 36 hours, the only data allowed to remain on disk falls within the ranges defined in Table 3-12.

Finally, data that is seven days older than its time of observation is either deleted or stored on tape. Only synoptic land, mandatory and significant Pibal and Raob, CLIMAT, CLIMAT Temp, METAR, and Automatic 17-station observations will be saved on tape, and then only for those stations within Saudi Arabia'a zone or responsibility as a Regional Telecommunications Hub. (13)

This data is stored on tape by Data Type, and there will be one primary and two back-up tapes for each year's worth of data for each Type. Once these bulletins have been saved on tape, all seven-day-old information is deleted on disk. This process is continuously and automatically carried out by a File Maintenance Program. (13)

RANGES FOR SHORT-TERM DATA STORAGE

Data within these Block - Stations		
17000	to	17399
40000	to	40149
40350	to	40999
62000	to	63599

Data within these longitude and latitudes			
0	to	40	Degrees South
20	to	80	Degrees East

TABLE 3-12

Strictly speaking, only those CDB Files currently on disk are considered as part of the active CDB. Archived files reenter the CDB when they are retrieved. It follows that tapes of historical weather data waiting to be decoded by the ADP as well as any tapes of plots generated by SAVID are also not thought of as part of the CDB, only as elements in the tape library.

The CDB is a data base upon which programs act. It does not have its own programs, but rather has programs associated with it. For ease of reference the CDB can be spoken of as "having" or "using" programs. In particular, there are three types of programs used by the CDB: the CDB Text File Programs, the OAS File Maintenance Programs, and the Filename Inquiry Programs. (13)

Those that require the most operator interaction are the ones dealing with the CDB Text Files. Next come the programs dealing with the OAS Files temporary stored in the CDB. Finally, there are the Filename Inquiry Programs which operate with both file types. These programs simply construct and decode filenames. (13)

In actual operation, most of these programs will be run according to a schedule, so that maintenance tasks will be routinely and regularly perfomed. Such a schedule is always open to change as conditions require. (13)

The CDB is primarily concerned with its own CDB Text Files and uses the following categories of programs is dealing with them:

File Maintenance,
Data Maintenance, and
Application Programs

These programs, in combination with the CDB Control Files, provide mechanisms for storing, maintaining, accessing, editing, and using the data the CDB supports. Each of these program types will be summarized below, after a brief discussion of Control Files. (13)

Many of the CDB programs require command information during their operation. For example, the ARCHIVE program needs, for specific Data Types, a list of the stations it should store on tape for that Type. This list could be built into the program itself, but then any changes to the list would necessitate changes to the program, and this in turn would require that the program be recompiled. Since this would be a lengthy process, the list of stations is kept in a separate, special file called a Control File. Each Data Type has its own Control File which ARCHIVE can then access whenever it runs. For example, the SLCRTH Control File contains the list of synoptic land stations; this list can be changed by editing SLCRTH, without having to do anything to ARCHIVE. When ARCHIVE runs, it simply accesses SLCRTH for the list. (13)

The File Maintenance Programs will maintain the files currently on disk. They delete files no longer needed, archive files to be saved on tape, and restore files previously archived. The RECCLN, ARCHIVE and DELFILE programs are incorporated into the AFT18 program collection to make the maintenance task easy and regular. (13)

RECCLN deletes records from CDB Text Files when those records are older than 36 hours. Specifically, it deletes the records of all stations that fall outside the ranges listed in Table 3-12 RECCLN operates by calling the TRANFSO program. TRANFSO accesses the CLNDATE Control File for the start date of the record cleanup and the LLRTH Control File for the latitude-longitude boundaries. While RECCLN can be operated as a separate program, it will normally be executed automatically as part of the AFT18 program collection to ensure its daily use.(13)

ARCHIVE will do the day-to-day archival of those stations and Data Types considered worthy of long-term storage. Separate tapes store particular stations for different Data Types. The stations must be within the station/geographic boundaries described for RECCLN, so ARCHIVE is not affected by the running of RECCLN. In fact, ARCHIVE is also normally executed as part of the AFT18 program rather than as a separate, independent program. (13)

ARCHIVE executes the ARCH10 program. ARCH10 first issues a tape request for a primary and then two back-up tapes. A complete set of data will be written to each tape for security reasons. This is so one complete set of data can be stored outside the Center, while still making two complete sets available within it. This insures against the potential loss of a tape or tapes through accident or error. These tapes are the historical data base and will be the only source of their stored data once the DELFILE program (described below) is run.(13)

Next, ARCH10 reads the start date for archival from the TAPELST Control File. Only data that falls within the time period from the determined start time up to 24 hours prior to the time of the program's execution will be archived. (13)

ARCH20 writes the data for each of eight Data Types to a different set of primary and back-up tapes (i.e. each set of tapes stores a single Data Type). In addition, only the data for certain stations for each Type is stored, and ARCH20 reads the Control Files for the respective Data Types to determine what these stations are. Thus, the list of stations to be archived can be modified simply by modifying their particular Control File. The eight Data Types and their respective Control Files are listed in Table 3-13. (13)

After ARCHIVE has been run, DELFILE is executed to delete all CDB Text Files older than a specified number of days so that the disk will not get cluttered with too much data. This means that the files just archived will now be deleted on disk. To insure the correct order of program execution, AFT18 contains DELFILE, too. (13)

DELFILE executes the DELETEO program. DELETEO accesses the TAPELST Control File for the start date of the file deletion process; it then accesses DELDAYS to find out how many days back in time prior to the last 24 hours to go before beginning the file deletion process. Initially, DELDAYS will be set at 6. This will ensure that at least the last 7 days worth of data will be kept current on disk. (13)

THE ARCHIVED DATA TYPES AND THEIR CONTROL FILES

NAME	DATA TYPE	CONTROL FILE
SLC	Synoptic Land	SLCRTH
RMC	Raob Mandatory	RMCRTH
RSC	Raob Significant	RSCRTH
PIC	Pibal	PICRTH
CLS	CLIMAT	CLSRTH
CLU	CLIMAT Temp	CLURTH
SAC	METAR	SACRTH
A17	Automatic 17-Stations	A17RTH

TABLE 3-13

RESTORE is used to restore data previously archived on tape by ARCHIVE. RESTORE executes the RESTR10 program which asks the operator for the Data Type, time period, and the stations to be restored. It then examines the TAPELST file to determine the appropriate tape to be mounted as specified by the operator and issues a tape request. (13)

RESTR10 executes RESTR20 which actually reads the data from the tape. If the stations to be restored were not specified by the operator, the stations listed in the Control File for the particular Data Type will be the ones restored. (13)

The files returned to disk by RESTORE that are outside the range of files deleted by DELFILE will have to be individually deleted by the KILLIT program. KILLIT requires such files to be specified by Data Type and start and stop date-times. For this reason, careful track should be kept of all files restored so that they can be eventually deleted. Otherwise, the disk could easily become cluttered with restored files. (13)

The historical data returned to disk by RESTORE which falls outside the range of DELFILE will not be deleted by any of the routinely run programs. These CDB Text Files will have to be specifically deleted by the KILLIT Program. KILLIT will need the Data Type and start and stop date-times of all files to be erased before it can complete the deletion process. (13)

AFT18 is a collection of CDB maintenance programs. Running it actually executes the RECCLN, CLMSYN, CLMTMP, ARCHIVE, and DELFILE programs. Thus AFT18 deletes data outside the defined area of interest to Saudi Arabia, updates the two CLIMAT reports, archives the appropriate data, and then cleans out all old files. ADT 18 should be run once every 24 hours. (13)

Data Maintenance programs deal with the actual data. They are used to display, edit, and delete data as need be. The Data Type templates are essential for the proper use of these programs, since they will be needed to read the data as it is displayed on the screen. (13)

The GETOBS program will retrieve data for any Data Type, time period, and station or stations. The data can be displayed on a CRT screen and/or printed out in hard copy as the operator desires. (13)

EDITOBS accesses the same range of data as GETOBS but for the purpose of making it available to an operator to edit using the CDC Edit program. It first executes PREPFLO which uses prompts to elicit from the operator the Data Type, time period, and station(s) of the data to be edited. This data is written to the TAPE31 file which is then edited by the operator so that the actual editing changes can be made. When the edit session has ended, the REPLFLO program writes the parameters that were changed back into the appropriate CDB files. An "E" representing "human edit" will be written into the data flag column of every observation that received a change to at least one of its parameters. (13)

Changing parameters can potentially create more problems than it solves and so sould only be done when it contributes to the maintenance of an accurate data base. As a safeguard, if the operator misaligns characters during an edit session, REPLFLO will normally reject them by terminating. (13)

The DELOBS program is used to delete selected observations from the data base, and so like EDITOBS should be used with caution. DELOBS executes DELOBSO. The latter program asks the operator to specify the Data Type and time of the observation(s) to be deleted. It then asks for confirmation that the observations it has found should, indeed, be deleted before actually going ahead and doing so. (13)

The Application Programs use the CDB's data for a variety of purposes. These include the production of windroses as well as the generation of station summary and CLIMAT reports. The CLIMAT programs are normally executed as a part of AFT18. (13)

The REPORT Program generates a summary report of various meteorological parameters for given stations during a particular month. Thus, REPORT uses the REPORTO program to ask the operator to enter the stations to process for the report and for the year and month of the analysis. If particular stations are not requested, then all the stations listed in the SUMMARY Control File will be reported on. (13)

REPORTO computes averages and does analyses on whatever data it finds for the particular station(s) and time period. It keeps track of the number of consecutive unsuccessful attempts it makes at retrieving CDB files for the data. When the count reaches 24 (which would represent three days of synoptic data or six days of Pibal), the operator is informed of the missing data and is asked whether the program should continue or should be terminated for lack of data. The report's summary tables are printed out when the program is through.(13)

The DATAR program is used to generate a listing of all observations for a given year, month, Data Type, and up to 10 variables. DATAR reports are only produced for certain Data Types: SLC (synoptic), RMC (mandatory Raob only), PIC (mandatory Pibal only), SAC (METAR), and A17 (Auto 17-Stations). (13)

Up to ten variables can be asked for, and the program will generate a three-page report for each of them. The report lists hourly summaries of the variable for the entire month with each column representing a day and each row an hourly period of the day. The averages of all the hours of each day and of all the hourly periods for the entire month are also given.(13)

WNDROSE analyses wind speed and direction for a specified year and month, and creates a windrose plot from the summarized results. This plot can then be displayed on the Tektronix 4014 or printed out in hard copy on the Versatec. (13)

The WINDRSO program is initiated by WNDROSE. It asks the operator for the year, month and station for which a plot is to be generated. WINDRSO itself determines the best intervals for the final display, but the operator can override these computed intervals and specify his own. (13)

If the windrose is to be displayed on the 4014, then the program should be executed on that terminal. If it is to be printed in hard copy on the Versatec, a tape request is issued for an unlabelled tape and then the VERSTPP program is run. VERSTPP asks the operator to specify the paper size the plot should be printed on; it then dumps the plot file to tape and converts all vectors to the MSS format. (13)

CLMSYN is used to generate the monthly CLIMAT summary reports for the Saudi Arabian Synop stations. Since this should be done with regularity, both CLMSYN and CLMTMP have been included in AFT18 so that they do not have to be manually submitted. (13)

CLMSYN uses the CLMGNSO program to read the CLSRTH Control File for the list of stations for which CLIMAT reports are to be generated. Then, it accesses the CLIMATS file, repeatedly, for the actual running totals and monthly averages. Based on information found in CLIMATS, the program will report the processing period pefore proceeding, and, as was the case with REPORT, it will keep track of missing data and inform the operator accordingly. (13)

CLMTMP is used to generate the monthly CLIMAT summaries for Saudi Arabian upper air stations, and is included in the AFT18 program. CLMTMP uses CLMGNTO to access the CLURTH Control File for the station list. The CLIMATU file is used for temporary storage of the running averages for all parameters for the "OOZ", "12Z", and "OOZ + 12Z" data. The same test used in the Synop CLIMAT program is used here for missing data. Once the data for an entire month is analysed, CLMGNTO writes the monthly means. (13)

File Maintenance programs dedicated to the maintenance of files destined for use by the OAS. They are used for the deletion and clean-up of records and for the creation of a LID record, if this is needed. In normal operation, the AFT06 program is the one that will be used on a regular basis. (13)

The DEL24, DELIN, and DELOUT programs are used to delete records for specified time periods from the following files:

Grid Files	Raw Data	Climatology
ODSIGD	ODSIRD	ODSICD
ODSIGK	ODSIRK	ODSICK

For each of the three file sets, the data resides in the ODSIXD file and a pointer to that data resides in the ODSIXX file. When the DEL24, DELIN, and DELOUT programs are executed, they delete the pointer to the data. This means that the files remain the same size with unusable space being taken up by inaccessible data. DEL24 deletes all records for the last 24-hour period, while DELIN deletes all records inside a data-time range and DELOUT deletes all records outside such range. (13)

The DEL24W, DELINW, DELOUTW, and CLEANUP programs are used for deleting the record pointer in ODSIXK and/or cleaning out unusable data from the ODSIXD files to save space. In all four programs, usable records are copies over to a temporary file. When the copy operation is complete, the old ODSIXD and ODSIXK files are deleted and the temporary files are renamed to take their place. DEL24W, DELINW, and DELOUTW correspond to DEL24, DELIN, and DELOUT respectively. CLEANUP makes no check against time and does not delete any records in the copy process. (13)

Normal maintenance calls for the use of the DEL24W program for the routine, daily selection of OAS files. To make the use of DEL24W easier, it has been made a part of the AFT06 program which is executed instead. (13)

Finally, the LID program is used to recreate the LID record in the ODSIGD and ODSIGK files, should the need arise. (13)

3.3 ORGANIZATION AND FACILITIES

The Meteorlogy and Environmental Protection Administration (MEPA) has established the National Meteorological and Environmental Center (NMEC) as the major element in their overall Meteorological Upgrade Project. NMEC is located northwest of Jeddah about 15 kilometers from MEPA Headquarters. The NMEC is comprised of the following sections: Data Center, Forecast Center, Climatology, Air Quality Laboratory, Communications, Training, Supply and Equipment, amd Maintenance. The first three are the application sections and will be discussed in the subsequent sections.

Figure 3-8 is a functional diagram of NMEC. Incoming data is shown to left of the Data Center and outgoing data and products to the right. The operational sections are depicted below the Data Center and the support sections at the bottom of the Diagram. The two satellite ground stations are located in the NMEC Compound. METEOSAT provides geostationary infrared and visual imagery and NOAA produces higher resolution data from polar orbiting satellites. METEOSAT also relays data colected by the Kingdom's automatic weather stations. Conventional weather data are received by landlines from the Main Communication Center. The Forecast Center uses computer data to finalize forecast products which are then ingested by the Data Center for distribution to users. The Climatology Center accesses the climate data base to perform statistical studies. The Calibration Laboratory monitors air quality data and performs baseline checks in order to schedule maintenance on the remote sensors.

NMEC FUNCTIONAL DIAGRAM

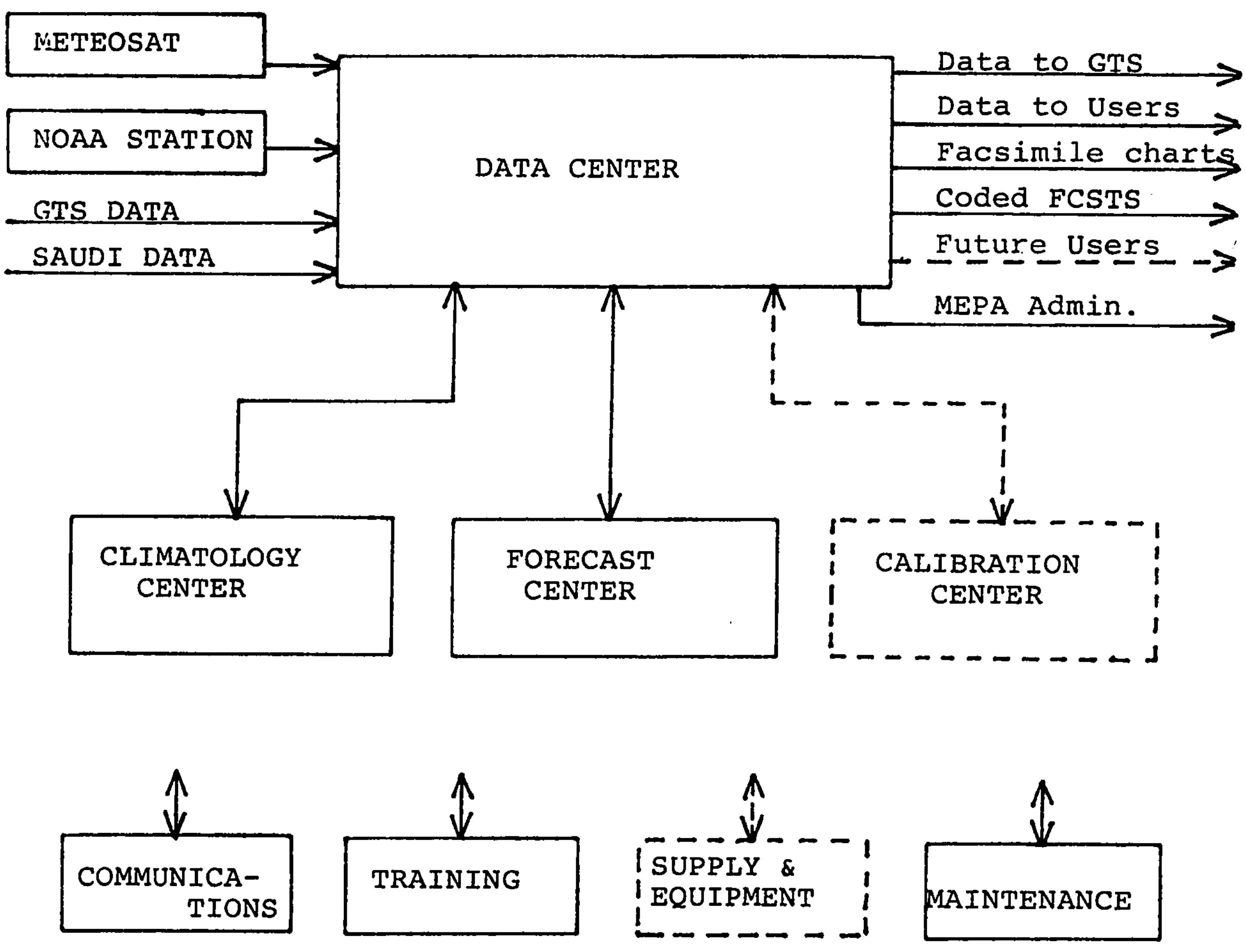


FIGURE 3-8

The on-site sections of Communications, Training, Supply and Equipment and Maintenance are in a supporting role, and react to the requirements of the operational centers. MEPA run their administrative programs from a remote terminal in Headquarters.

3.3 a) <u>Data Center</u>

The first phase in the building of NMEC was the construction of the Data Center. Upgrading the data handling systems, forecasting, climatology, and other sections was dependent on automated data processing, and so the establishment of the Data Center was logically the first step. MEPA has three objectives in the design and signing of the Data Center:

1. Automation of the Meteorological data communication system.
2. Upgrading, development, and automation of environment data processing and forecasting and other related functions.
3. Upgrading and automation of administrative functions in MEPA.

These objectives were then translated into specific requirements:

1) <u>Automation of Meteorological Telecommunication Including Message Switching</u>

MEPA must have an automatic environmental data collection system for collecting and controlling data from national and international sources. The system must be capable of collecting information from manned stations via cable and radio circuits, from unmanned automatic stations, and from remote sensors such as those mounted on meteorological satellites. The system must accomodate international circuits of various speeds ranging from 50 bits per second to about 2,400 bits per second, and of considerable volume (hemispheric and tropical environmental data). The processed information can be in alphanumeric and facsimile form. The system must be capable of message selection and switching in accordance with predetermined programs and allow rapid transmission of information to national and international centers.

2) Upgrading, Development, and Automation of Environmental Data Processing and Forecasting and Other Related Functions

a) Establishment of historical and real-time environmental data base.

It was deemed essential that a data base for real and delayed time activities be established. The capability must exist for responding immediately to real time enquiries of actual environmental conditions. It is also essential that the data collected in real or delayed time mode (through data entry stations) be validated, quality controlled and stored.

Capability must exist for automatic weather charts plotting (the maximum size of the maps 100 x 100 cm, and they contain about 250 stations). Transferring the data to microfilms and microfiches and converting the data into pictorial forms should also be possible.

b) Upgrading and automation of weather and marine forecasting and development of numerical environmental prediction capabilities and other highly advanced functions.

This actually the central objective of the whole project -- that is to provide quantitative, more accurate forecasts for aviation and marine purposes, bring in modern computer methods for analyzing the atmospheric data and making the forecasts, and expand the activities to include global prediction and long-range weather forecasting. Equally, if not more important, for Saudi Arabia are the real life applications of environmental data. Solar energy research, land reclamation, agriculture, weather modification, and construction industry are only few examples where improved meteorological services can be of vital importance.

3) <u>Upgrade and Automation of Administrative Functions of MEPA</u>

The project also aims at automation of all administrative transactions. Personnel and payroll, inventory information concerning equipment, furniture, stationary and spare parts should be automated. Financial transactions should also be automated, and a secure method of checking and verifying journal entries efficiently and quickly is necessary. It should also be possible to obtain detailed or summary information from the ledger at any point in the fiscal year.

The Hardware System Confirguration was choosen to satisfy all the stated requirements. Figure 3-9 shows the equipment complement for the National Environmental Data Center. Two front end processors, each equipped with 128K bytes of main memory, are provided for the Integrated Meteorological Communications and Graphics System (IMCAGS) which handles all of the functions of the Message Switch. A direct view storage tube allows a forecaster to view graphics before delivering the output to a 100 cm plotter. The disk system of the dual processors provides 150 M bytes of storage. Each computer is equipped with a dual drive magnetic tape system. A shared peripheral set contains the following:

* Card reader, card punch
* Three line printers
* Three alphanumeric CRT Terminals, and
* analog-to-digital and digital-to-analog converters.

Each computer also contains line interfaces for synchronous and asynchronous communication over the 50 to 2,400 baud range. (14)

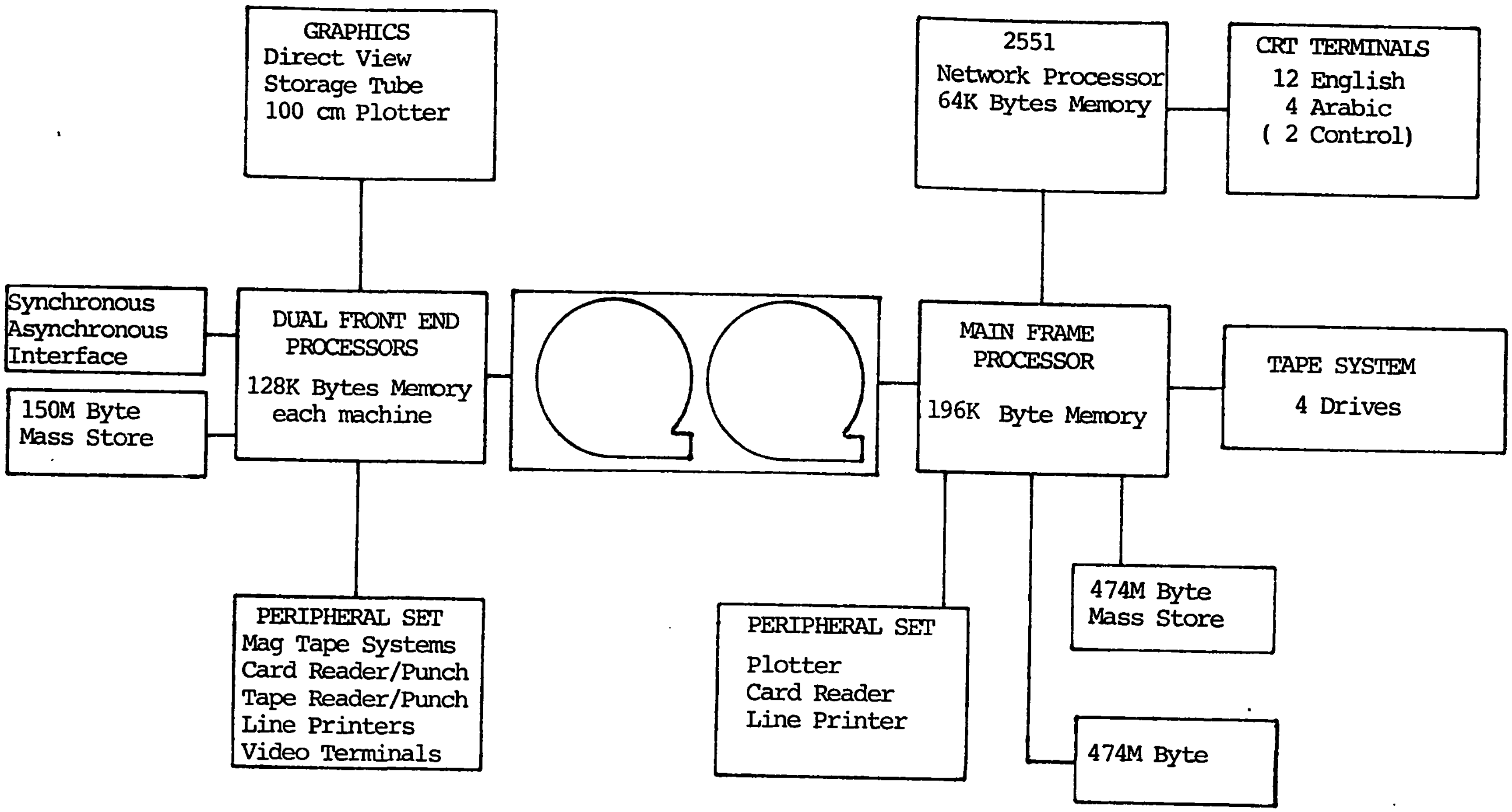


FIGURE 3-9

DATA CENTER HARDWARE CONFIGURATION

Data from IMCAGS are written on magnetic tape. The tapes are transported to the medium-scale computer for entry of data in the data base. The main processor serves as the data base management, environmental processing, and administrative processing computer. It is equipped with 196K bytes of main memory and a magnetic tape system with four drives. Its peripheral set contains a general purpose plotter, card reader and punch, and a line printer. Access to the data base is obtained via alphanumeric cathode ray tube (CRT) terminals (Arabic and English) interfaced to the main frame through a small processor, the 2551 equipped with 64K bytes of memory. Four disk drives provide additional mass storage for the main frame. Tables 3-14, 3-15 list the system's hardware.

The management of the Data Center is accomplished by the Data Center Director and his assistant, the Data Center Manager. Operations and Maintenance is sub-divided into four sections: Computer Operations, Scientific Programming, Administrative Programming, and Hardware Maintenance.

Computer Operations has two supervisors, 10 message switch operators, 5 main frame operators, one message switch system analyst and one main frame system analyst. Two system analysts and four programmers comprise the scientific programming section. The administrative programming section has one system analyst and four programmers. Hardware maintenance is performed by two contracted engineers. The data center has a total of 30 personnel.

MESSAGE SWITCH HARDWARD

REFERENCE	DESIGNATION	QTY
18-20	Control Processor	2
1811	C.R.T. Console	2
1882-32	Memory Module 32KW	8
1833-1	SMD Interface	2
1833-2	SMD Interface	2
1833-3	SMD Controller	2
1867-20	SMD Storage Module Drice	6
1860-3	Magnetic Tape Subsystem	2
1828-1	Reada/Printa Controller	2
1829-30	Card Reader	2
1827-60	Linc Printer	1
1887-4	Cabinct	2
QSE	Expansion Chassis-Single access	1
QSE	Expansion Chassis Dual access	1
QSE	4 Synchronous lines adapter	4
1843-3	6 Asynchronous lines adapter	4
1843-4	10 Asynchronous lines adapter	4
752-20	C.R.T. Console	2
BQSE	Telegraphic level convertor	1
*QSE	Fallback switch	1
TEK 4014	Graphic C.R.T. Tecktronic	2
	Versatic Off-line 42" plotter	1
	Versatec Off-line 22" plotter	1
*QSE	Quote for special equipment	

TABLE 3-14

MAIN FRAME HARDWARE

REFERENCE	DESIGNATION	QTY
171	Central Processor 196K	1
10380-1	Compare Move Unit	1
10381	Data Channel Converter	1
7030-102	Extended core Storage, 262K	1
10318-1	ECS Coupler	1
7154=2	Mass Storage Controller	1
7021-31	Mag. Tape Controller	1
679-3	9 Track Tape Drive	4
844-41	Mass Storage Drive	4
3447-2	Card Reader Controller	1
405	Card Reader	1
3446-2	Card Punch Controller	1
415	Card Punch	1
580-120	Line Printer	1
596-1	Print Train	1
2551	Network Processing Unit 64K	1
2554-32	Memory Increment	1
2558-3	Coupler	1
752-20	CRT Display	13
2560-1	Communications Line Adaptor	8
10401	CLA Cable	17
QSE	751 Display with Arabic Characters	4

TABLE 3-15

3.3 b) Communications Center

This center will provide the following:

1. New HF Links

   Improved Simplex HF links betweeb each out-station and regional collection centers with Visual Display Units (VDUs) on both ends of each link. (15)

2. Seventeen automatic weather stations and related equipment

   This will supply seventeen automatic weather stations similar to those currently in use in the Empty Quarter. Four of these stations will be equipped to make marine measurements and six will be equipped for air pollution measurements. In addition, equipment will be provided for the receipt of TIROS-N and Meteosat meteorological satellite pictures.

3. Meteosat link for data collection

   All data from the seventeen new stations will be transmitted to the European Space Agency's Meteorological Satellite (Meteosat). A Meteosat receiving station will be built at the Jeddah Data Center for reception of the observational data. Each station will transmit once each hour. (16)

4. Meteorological satellite image reception and processing

Equipment will be provided at the Jeddah Data Center for the acquisition and display of pictures of the earth taken by satellites in the visible and infrared bands. Pictures will be received from both TIROS-N (an orbiting satellite) and Meteosat (a stationary satellite). A digital computer will allow a user to see the images with latitude/longitude lines and coastlines superimposed. TIROS-N passes will be assembled in a mosaic on a mercator map projection. (16)

5. Air pollution forecasting

Software will be provided which will allow a prediction of air quality in the vicinity of each of the air pollution stations. It will also be possible to predict pollutant concentration at various points around the monitors dependent on the prevailing wind conditions. (16)

3.3 c) FORECAST CENTER

The MEPA effort to upgrade the present manual forecasting system into a state-of-the-art computer based meteorological system must be a much longer term conversion than modernization of data handling and building of the data center. The purpose of the new forecast center is to improve forecasting capability and at the same time maximize the utilization of scarce, highly trained manpower resources. The mission of the forecast center is to provide operational meteorological and environmental products to satisfy aviation, military, marine, agricultural, air quality, and public service requirements for the Kingdom of Saudi Arabia. The automation portion of the upgrade can be satisfied by a straight forward system engineering approach. However, the education and training of a highly qualified staff to optimize the automated capability is the long-term portion and it cannot be accelerated or condenced in time. The cost trade-off is to eliminate forecasting services at the out stations and reduce them to briefing and/or observing sites only.

The automated systems already discussed are adequate for the first phase of the forecast center's operations. The phase one objective is to perform the forecasting functions at the center which are currently being accomplished at various locations in the Kingdom, and with an increased proficiency level. Forecast procedure for Saudi Arabia and immediate surrounding area will be labor intensive with emphasis on manual procedures. International support on the hemispheric scale will rely mainly on computer output produced locally or imported by facsimile or as grid point data which will be processed by the computer center.

When the forecast center becomes established it will immediately provide the following products and services:

1. Terminal Aerodrome Forecasts (TAFS) for the Kingdom's 22 airfields. TAF's will be issues four times daily with 24 hours valid periods. The TAFS will be the sole responsibility of the forecast center and will be metwatched and amended as required.
2. Issue area forecasts for a radius of 50 miles for the six major international airports. These forecasts will be issued twice daily with an 18 hour valid period.
3. Prepare scripts for national radio and TV Stations. Prepare a daily weather forecast and summary of the Kingdom.
4. Prepare significant weather advisories for aircraft in flight to satisfy WMO SIGMET requirements.
5. Prepare international flight briefing package for facsimile transmission to the Kingdom's airports twice daily. The package will include 300 mb, 250 mb, 200 mb, significant weather and maximum wind analysis;and 300 mb, 250 mb, 200 mb, significant weather, and maximum wind 24 hour prognostic charts.
6. Prepare Route Forecasts (ROFORS) during the Hajj Season. (17)

To support the forecaster center's operations, the data center will receive and process all the Kingdom's synoptic, METAR, special METAR and upper air reports from manual and automated stations, Global Telecommunication data to include hemispheric synoptic, 3 hourly upper air and selected TAFS and METARS and prognostic fields received by facsimile or as grid point data. The computer will plot all required data on the chart scale selected by the forecasters. The objective analysis and enteraction by the forecasters through SAVID will provide analysis at all atmospheric standard levels in the large scale. These analysis will be used directly for international support products, and as an aid in producing the manually prepared Saudi Arabian analysis. The objective analysis programme will store the hemispheric grid point prognositic value for analysis by SAVID.

The forecast center will be staffed with 18 journeyman forecasters, 12 observer technicians, a chief forecaster and the center director for a total of 32 people.

3.3 d) CLIMATOLOGY CENTER

Sixteen highly skilled climatologists are assigned to the NMEC Climatology Center and their activities are managed by the center director. Direct interactive access to the data center's climate data base is provided by four visual display units loacted in their building. They have access to addition data in their location from stored satellite visual imagery and infrared pictures. These are achieved by a photographic process which reduces the images to 35 mm size. Although all Saudi Arabian data is archived on magnetic tape by the data center is planned, significant programming remains to be accomplished before that data can be fully processed by the center.

4.0 AUTOMATED METEOROLOGICAL DATA HANDLING SYSTEM PERFORMANCE ANALYSIS

The performance analysis and evaluation provided here are of an interim nature since the system designed in Section 3 is not as yet fully operational. The upgraded HF communication network has been installed, but not all stations have adequately retrained observers to use the new equipment. The system is in operation to transmit data from the regional sub collection centers to the main Communications Center. The automatic message switch programming to sort messages and assemble required bulletins automatically is currently being expanded and debugged. The large increase in capacity provided by the switch has prompted the inclusion of data never utilized before. (Data from ships at sea and consolidated data from World Meteorological Centers that is available on high speed circuits).

Some of the data used to compare old and new system performance was obtained from a series of tests where the automatic machinery was used in parallel with the operating manual system so that the results could be compared directly. In other instances the comparison is more qualitative. Items such as the appearance of a synoptic chart delivered by fascimile transmission or the ease of historical data retrieval. In most instances, there is not yet enough full time running experience to provide measures of data error level. Here too the results of analysis are of necessity, partly subjective.

The following sections present a comparison of the new and old systems with respect to the limitations of the operating manual system identified in Section 2.2.

4.1 Enhancement of Data Handling Capacity

The use of the computer based message switch removes any practical limitations on the number of messages that can be received. It does not change the incoming messages so that the period (time) of any one particular message arriving from outside the Kingdom has not been changed. Since it can accept messages directly from the in-country network, however, the manual transmission, transcription and tape punching operations have been eliminated. This reduces the MCC function from six minutes to forty five seconds.

Another consequence of introducing the message switch is due to its information processing speed capability. While a large proportion of the input data is at 75 band teletype speed, there are global services available which operate at over one hundred times this message speed. Arrangements have been made to connect a 9600 line from the World Meteorological Center in Offenbach, Germany to the message switch. This line provides up to 2100 messages per hour that will replace the low-speed intercepts.

The average message handling capacity has been increased by a factor of six. The time required for the transfer of in-Kingdom data has been reduced by a factor of twenty and the time required to assemble outgoing messages has been reduced by a factor of seven.

4.2 ERROR REDUCTION

The elimination of manual transfer of numerical data, and some editing of in-coming messages by the message switch has reduced the individual group error rate. It is difficult to assess quantitatively since there is no dependable experience data on the error rates of the manual system. Operations research studies have shown manual data reduction in repetitive routine procedures to be up to five percent at the point where data are first processed. A reduction in error rate is achieved primarily by the elimination of the subsequent manual data handling steps at the Regional Collection Centers and the Main Communications Center. The error rate was estimated in Section 2.2 to be ten percent. This means that since the original data error rate is five percent, the balance is effectively removed by elimination of transcription errors. The error rate discussion in Section 2.2 c) includes an estimate of missing data due to poor propagation of transmission line quality. The inclusion of a data MODEM with an improved signal to noise ratio of 20 db over the original voice transmission system allows better quality data transfer under good signal conditions and acceptable data transfer with poor or marginal signal levels. If twenty five percent of the data from the Kingdom sources are lost due to signal propagation, this translates to six hourly messages out of 24. Most of the message loss occurs at night when propagation conditions become poor and signal levels drop to the noise level. Signal levels change gradually (period of one to three hours). The 20 db advantage of the MODEM cab prolong the usefulness of a channel for one hour during fade out and make a channel useful one hour earlier than would be the case with the voice system.

In those cases where there is no sensible signal received at the station, there is no advantage to either system. If the real out-time due to propagation is reduced by one hour on each end, then there will be still four missing messages per day. This makes the missing data sixteen percent instead of twenty five which is a thirty six percent reduction in losses.

Incoming messages may have improper headers. In the manual system sometimes these can be corrected by the operator. The message switch selects, decodes and assembles using the header information. As a result it will reject messages for operator intervention that might have escaped the operator's attention. These address errors on the Global Telecommunications network are estimated to be two percent. Message switch editing will pick up at least half of these errors, reducing the throughput errors to one percent.

4.3 OUTPUT PRODUCT QUALITY

There are three factors considered in output data quality. The first is timeliness of a forecast product, the second is the quantity of data utilized in forecast preparation (which should improve the accuracy and resolution available), and third, the appearance and legibility of the synoptic map received at a user location (generally by fascimile reception).

The addition of the automatic plotter instrument reduces the initial map preparation (plotting data on a base map) from several hours to less than ten minutes. This is the largest single factor in reducing output time. At the same time the number of observation stations that can be plotted is increased by a factor of two. This is not the capacity of the system, but reflects only the inclusion of that data desired by the forecast function. The time saving shown for the timeliness of forecasts under the old system in item 7 of Table 4-1 would be considerably greater if the number of points plotted was doubled.

The automatic plotter produces a uniform line width high contrast map with uniform data groups attached to each point. This is superior to hand plotting of the same data unless the plotter is exceptionally skilled and takes a great deal of time in the map preparation.

The synoptic maps are transmitted by radio fascimile to users in different parts of the Kingdom. The quality of transmission is dependent on equipment maintenance, circuit noise, and original copy quality. In general, hand plotted data are not uniform and

SYSTEM PERFORMANCE COMPARISON

FACTOR	OLD	NEW	NOTE
1. Message Capacity/hour average	332	2100	Inlcudes Offenbach line
2. Message Assembly Time	6 min	45sec	Once data are all received
3. In-country message entry	7 min	20sec	All manual operation eliminated
4. Overall error rate (data)	10%	5%	Group estimates
5. Missing data	25%	16%	in-Kingdom services
6. Header errors	2%	1%	Requires operator intervention
7. Timeliness of forecasts	270min	150min	Total time to prepare
8. Plotted points	280	550	
9. Appearance as received	70%	95%	Fascimile Transmission Readability
10. Number of pressure level maps	4	13	
11. Monthly Climate report access	60day	10min	
12. Weather communications	168	65	Manpower required for
13. Data center	0	30	data acquisition, message building
14. Forecasters	180	120	and forecasting
15. Climatology	30	25	

TABLE 4-1

small line width numerals are easily lost. Examining a typical hand plotted map following transmission reveals some thirty percent of the information not readable. The same circuit transmitting the machine plotted map retains ninety five percent of the plotted data.

Automatic plotting allows a larger number of maps to be drawn in the allotted forecast time period. At best, manual plotting could produce maps for four pressure levels: surface, 750 mb, 500 mb and 250 mb. The automatic plot routines can provide maps for up to thirteen pressure levels.

No evaluation is made of the improvement in forecast quality due to computer assisted analysis. The computer utilizes fixed rules to interpret data while the analyst often uses flexible adapted rules to the specific situation.

No evaluation is made of the climate data base system because it has not accumulated enough data to exercise the features included. There is enough not running time to have accumulated monthly data sets. The access time for these sets can be compared for the old manual system compared to the retrieval from magnetic tape storage. The old system "lost" data in the mail and review cycle for periods of months. The new system provides for retrieval from archived magnetic tape records in a matter of minutes, largely dependent on locating the tape in the library and mounting it for reading.

4.4 MANPOWER IMPACTS

The manpower impact evaluation is estimated because the new system has not been fully functional and the old system is still in use. In the short term there has been an increase in manpower requirements because the systems are running in aparallel. and some debugging and modification of computer programs is required.

With the automatic message switch and outgoing message assembly, the manual teletype operators will be retained for some other function. The new system will require new skills for computer programmer, operators, librarian, data systems manager, etc. The total staff needed to operate the manual system data handling is approximately 378 . The number of personnel in various functions under the new system are shown at the bottom of Table 4-1.

There will be net saving of 138 operating personnel with the implementation of the new system. This saving in personnel are partially offset by a large increase in the skill levels required to operate the automatic system and a comparable increase in maintenance skills.

5.0 SUMMARY AND CONCLUSIONS

The purpose of this project was to upgrade the meteorological system by introducing a new system which will do the same job, but in a more timely and reliable manner with increased capability.

A comprehensive analysis and in-depth evaluation was done of the old system. It was based on how well the material and personnel resources were applied to perform the operational functions. A new system is introduced as an efficient replacement and I have shown in Chapter 4 that the new Automated Meteorological system is better operational than the system which was in use, because of the achievements:

1. The capability of handling more messages
2. Error rate reduction
3. Timeliness of messages
4. Manpower re-distribution
5. Better output product quality.

During the implementation phase some unforeseen parameters surfaced which caused events that were not planned in the scope of the upgrade.

MEPA decided to increase the observing network by building 17 new automatic reporting stations. These stations will relay their data via a satellite link to the computer center. Six of the automatic stations are equipped with sensors to measure air pollution and four to measure sea conditions. The new system has to cope with the greater data volume and to process the new data types. Hardware and software interface is added to the message switch to receive this unique data when the automatic station project becomes operational by February 1983.

Another added capability is support to the new pilot briefing office at the King Abdul Aziz Airport. This requires additional programming and equipment to transmit meteorological bulletins to their printers, satellite pictures, weather maps and diagrams by a fascimile circuit.

The institute of meteorology and arid lands at King Abdul Aziz University requested a direct link to MEPA computer center to provide an interactive access to the meteorological data base.

Similar requests were received from various governmental departments and from the private sector. Approval of most of these requests is essential and the data must be available to the users. These services were not planned and they constitute an addition capability that must be added to the system.

Savings in manpower in communications and forecasting were evident from the system performance analysis. However, the job descriptions of the reduced number of positions reflect much higher required skill levels. Examples are:

1. Scientific Programmers
2. Administrative Programmers
3. System Analyst
4. System Engineers
5. Software Librarian
6. Message Switch System Analyst
7. Computer Operator
8. Maintenance Technician
9. Satellite Imagery Analyst
10. Professional Meteorologist

Also additional training is necessary for the people in some of the positions that appear to be unchanged. The communications operators must have special training so that they can assemble and correct errors in messages interactively with the computer. Some of the maintenance technicians need intensive computer maintenance training to understand new technology and functions.

No plan can be perfect because requirements normally change with time and some program modifications must be accomodated during implementation. However, we have seen evidence that careful, in-depth system analysis approach would have minimized the unforeseen parameter discussed in this project.

In Chapter 3 and during the designing process, some of the good options were not considered because it was not possible to achieve due to some uncontrolled constraints.

One of those is option d in limit one which was using telephone lines to replace the voice communication network. Although, it was the best option, it was discarded due to the lack of available resources in the Ministry of PTT. This is now a viable option and should be incorporated in the communication network. This would provide a direct link from the out-stations to the computer message switch, and will reduce the time of transmission to only five minutes which is a reduction of 240 percent over the accepted option. A direct line will eliminate the need for the Regional Collection Centers for a significant manpower reduction on redistribution. Also, the use of dependable landlines or satellite circuits would eliminate the costly radio receiver and transmitter maintenance. The link would make possible a query-response procedure between the observation site and message switch computer.

The computer could be programmed to automatically request missing data or correction of an error in received message.

It is too early to conduct a qualitative analysis of the accuracy and reliability of the forecast products from the new system. The forecasting personnel need considerable training and experience of using computer generated analyses and prognoses before they can fully exploit that level of technology. That process is time consuming, cannot be condenced, or started before the computer center was fully operational.

The introduction of computer and modern communications technology eliminated or reduced to an acceptable level the limiting factors of the existing system. Manpower reductions provided a significant cost offset. However, the true cost in the longrun will be increased due to upgrade skill levels and maintenance of high technology equipment. Systems analysis and careful planning will minimize costly mistakes, but increased efficiency and productivity are achieved through a commitment to provide more costly human and material resources.

REFERENCES

(1) Technical Specifications for The Project
MEPA, September, 1978

(2) W.M.O. Technical Regulations No. 49,1975

(3) MEPA Personnel Register, 1982

(4) VITEL Telegraph Compatible V.D.U.
Automation and Technical Services (Communications)
Limited. Bridge Road Haywards Heath.
Sussex RH 16 1TY U.K.

(5) LA 2028 32 Tone Piccolo Modem
Racal Communications. Ltd.
Western Road. Bracknell, Berkshire RG 12
1 RG U.K.

(6) STC Lincompex Radio Link Terminal Ewuipment
TM 10A
Standard Telephones and Cables Ltd.

(7) Upgrading of Demostic Network
RACAL Communications Ltd.
NHGB/EP/ CSX 670/410 April 1978

(8) Integrated Message Switching and Graphics System User's
Manual,
Environmental Research and Technology
Concord, Massachusetts December 1980
Pages 1-1 to 1-6

(9) I.B.I.D. Pages 2-11 to 2-16

(10) Automatic Data Processor User's Guide,
Environmental Research and Technology
Concord, Massachusetts
December 1980 Pages 2-1 to 2-7

(11) Objective Analyses System User's Guide
Ocean Data Systems
Monterey, California
February 1981 Pages II-1 to II-7

(12) System for Analysis Verification and Interactive Display
User's Guide
Environmental Research and Technology
Concord, Massachusetts
December 1980 Pages 2-1 to 2-6

REFERENCES
(CONTINUED)

(13) Climate Data Base User's Guide,
Environmental Research and Technology
Concord, Massachusetts
December Pages 2-1 to 2-13

(14) Electronic Data Systems Technical Proposal
Dallas, Texas
November 1978

(15) RACAL and COLLINS Technical Proposal
London, U.K.
April 1978

(16) 17 Automatic Weather Stations Technical Proposal
Amartech
Saudi Arabia
February 1979

(17) MEPA User's Group Report
March 1982

(18) Some Methods of Climatological Analysis
W.M.O. No -199 TP 103

(19) Data Processing for Climatological Purposes
W.M.O. No -242. TP 132

(20) S.W. Corsline Computer Organization
Hardware/Software
Prentice-Hall, Ic.
1980

(21) Ivan Tomek. Introduction to Computer Organization
Computer Science Press
1978

(22) Donald A. Calahan. Computer - Radio Network Design
McGraw Hill, Inc.
1972

(23) Stanford Goldman. Frequency Analysis Modulation and Noise
Dover Publications, Inc.
1967

(24) Alan B. Marcovitz and James H. Pugsley
An Introduction to Switching System Design
John Wiley & Sons, Inc.
1971

(25) Henney. Radio Engineering Handbook
McGraw-Hill
1959

REFERENCES
(CONTINUED)

(26) Willaim L. Donn. Meteorology
McGraw-Hill, Inc.
1965

(27) Ya.L. Al'Pert. Radio Wave Propagation and The Ionosphere
Consultans Bureau
1963

(28) Thomas A. Blair and Robert C. Fite. Weather Elements
Prentice-Hall, Inc.
1965

(29) Guide on the Global Data Processing System
Volume 1 W.M.O. No.-305

(30) Data Processing in Meteorology
W.M.O. No.-180 TP 90

(31) Quantitative Meteorological Data from Satellites
W.M.O. No.-531

(32) Brochures, Sales Literature and Manuals about CDC. Cyber
170, 18-20, dics and tap units
Control Data Corp.
Minneapolis, Minnesota U.S.A.

APPENDIX A

1 - Surface Map

2 - Upper Air Map

PLEASE NOTE:

Oversize maps and charts are filmed in sections in the following manner:

LEFT TO RIGHT, TOP TO BOTTOM, WITH SMALL OVERLAPS

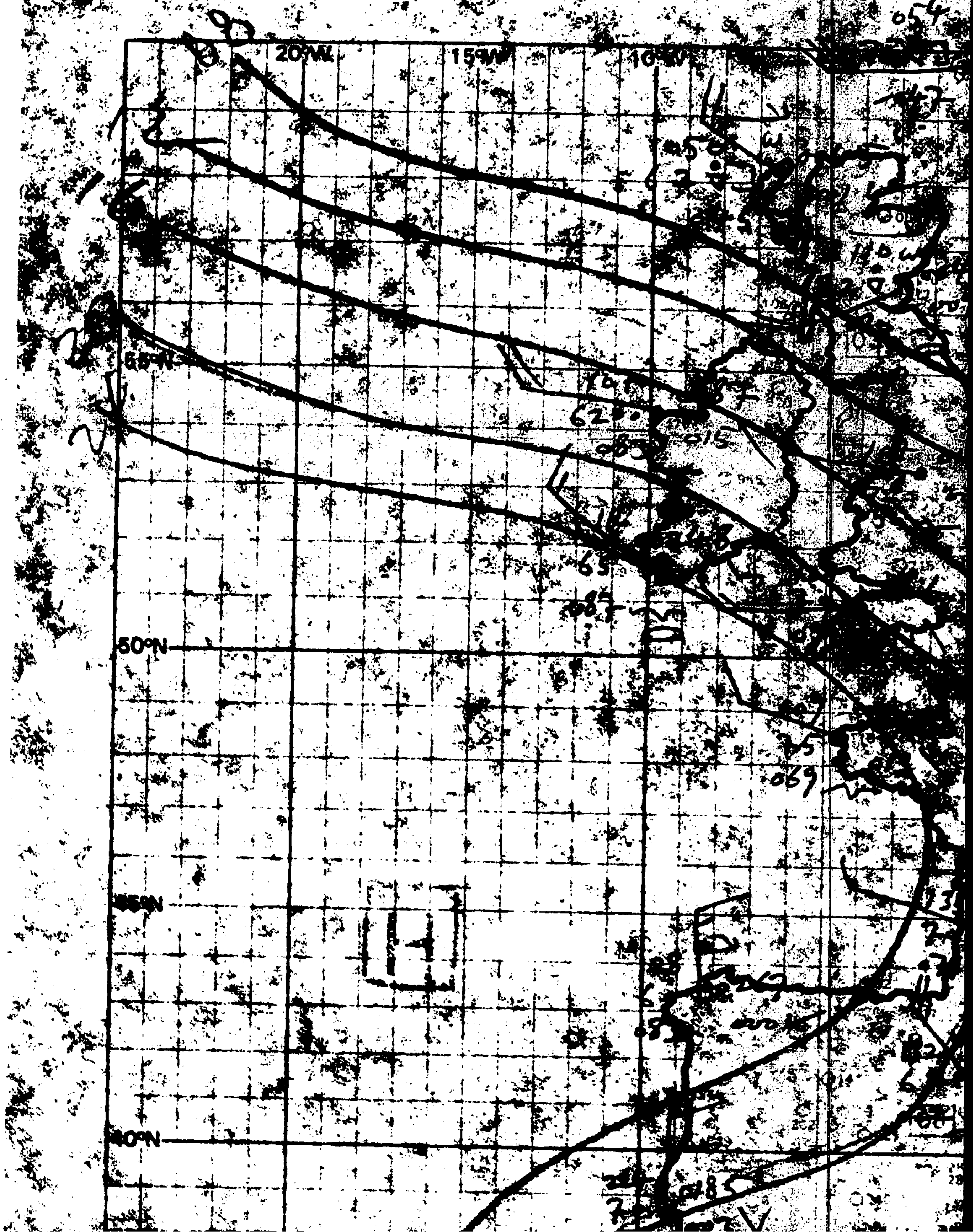
The following map or chart has been refilmed in its entirety at the end of this dissertation (not available on microfiche). A xerographic reproduction has been provided for paper copies and is inserted into the inside of the back cover.

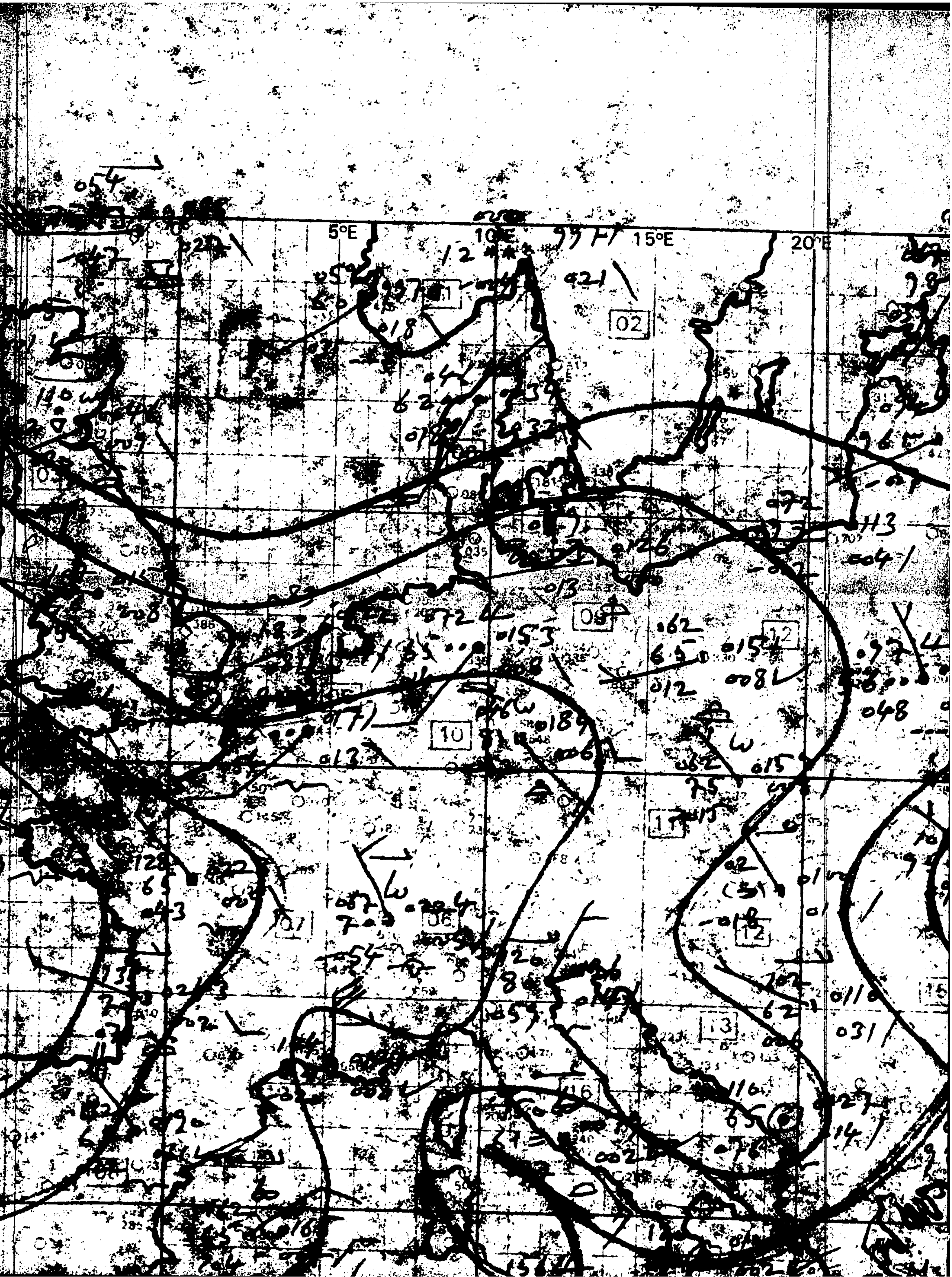
Black and white photographic prints (17" x 23") are available for an additional charge.

KINGDOM OF SAUDI ARABIA

MINISTRY OF DEFENCE & AVIATION

Meteorological Department





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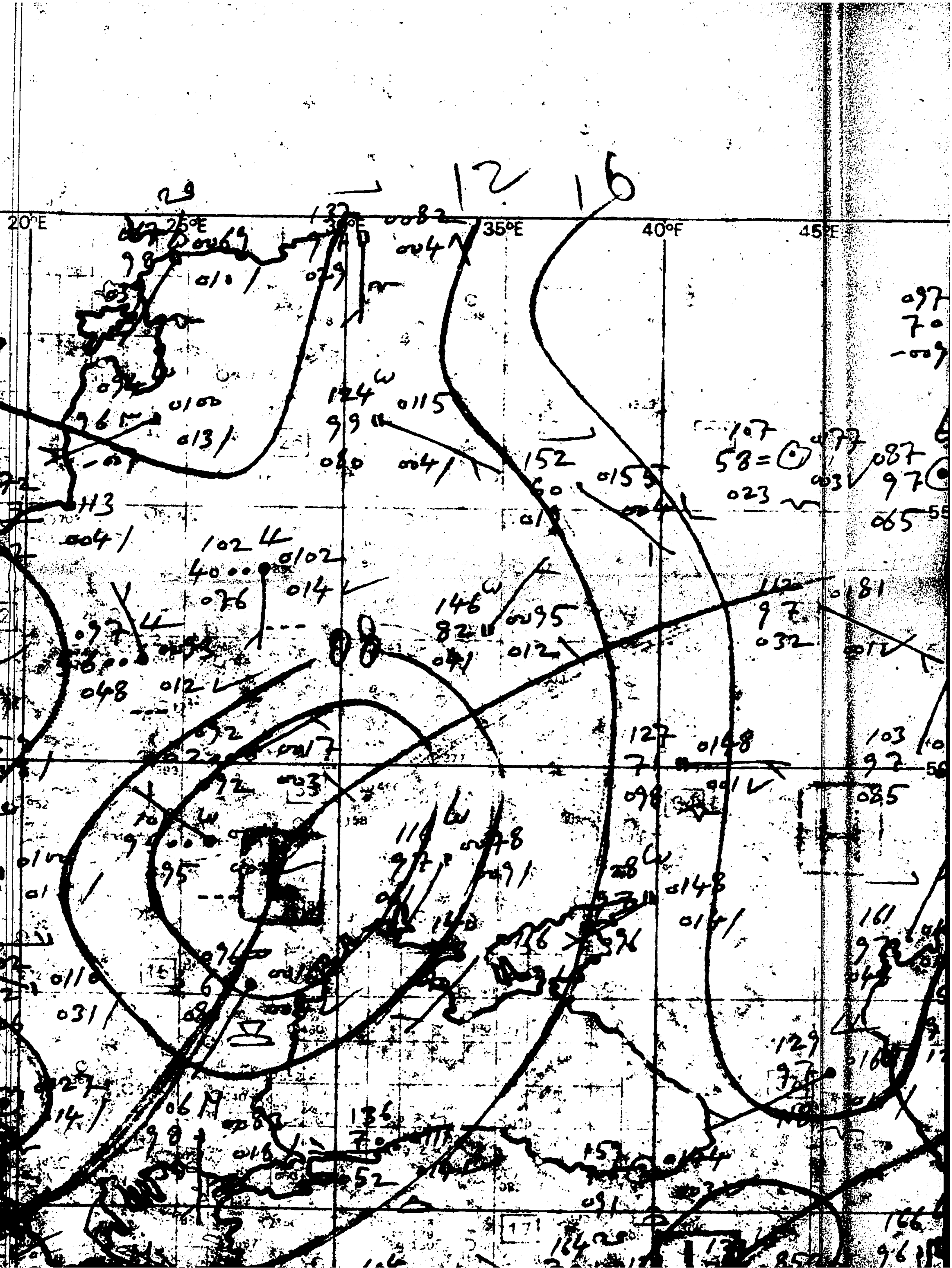

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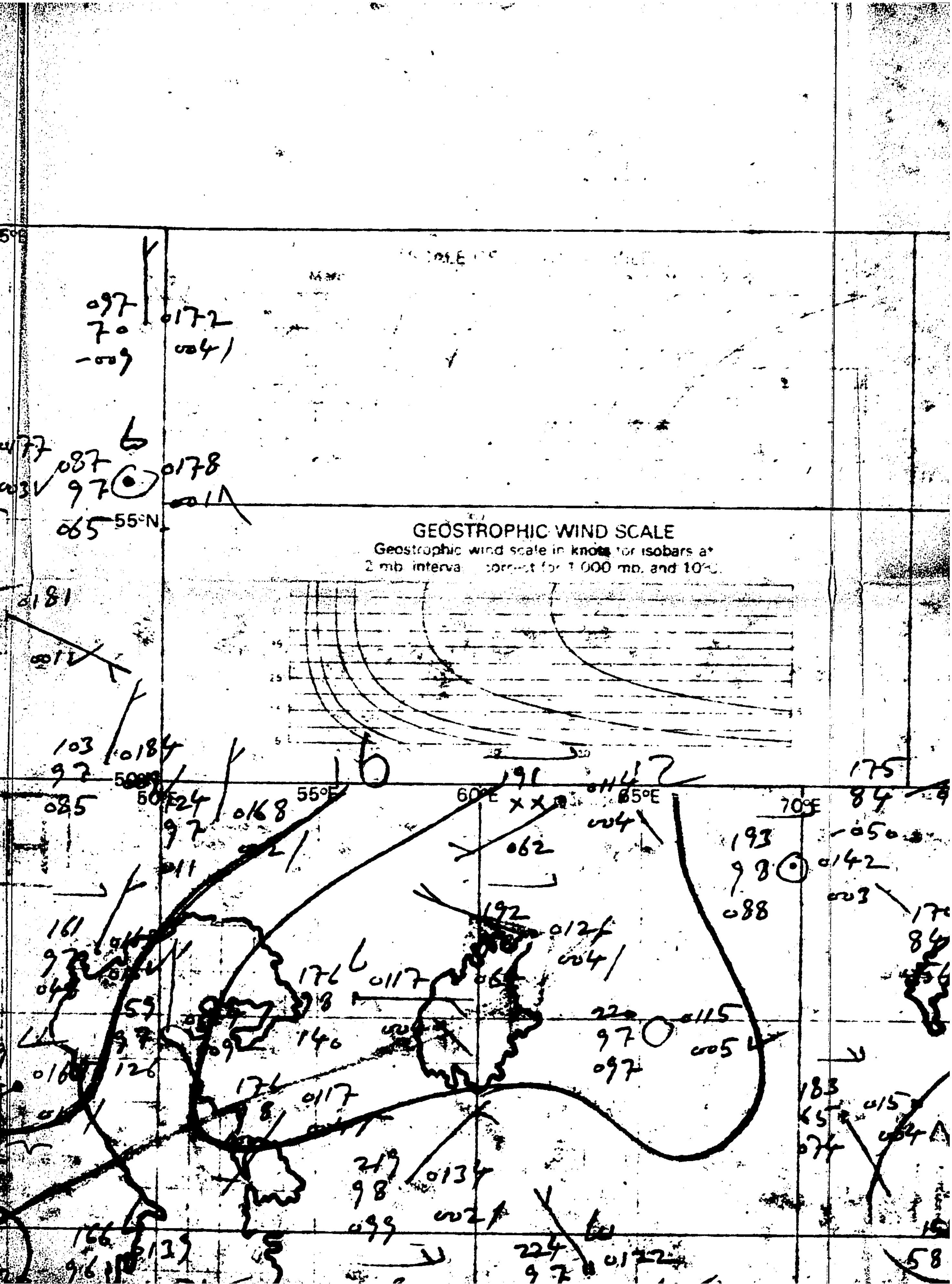
GEOSTROPHIC WIND SCALE
Geostrophic wind scale in knots for isobars at
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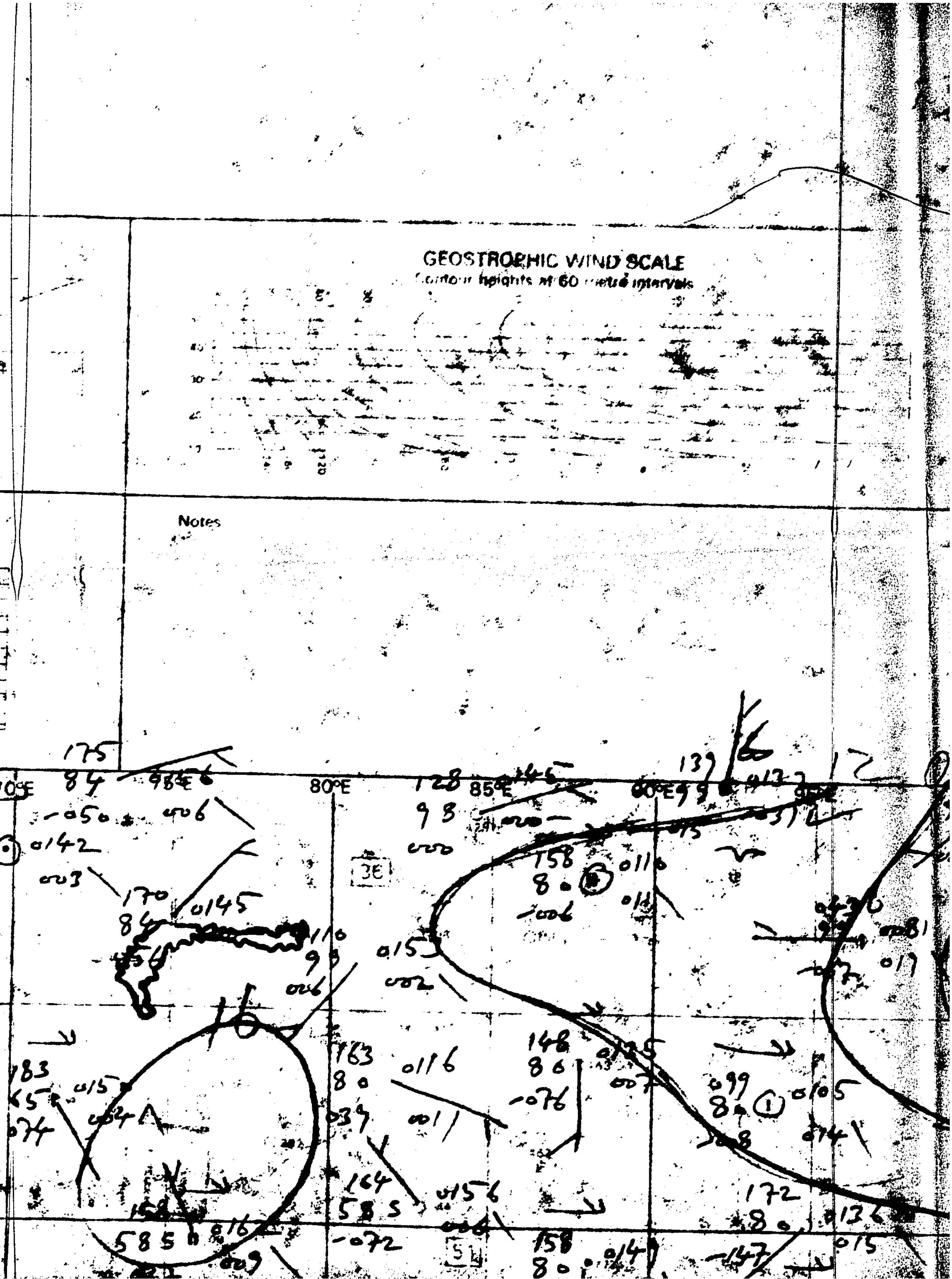
55°E
60°E
65°E
70°E


GEOSTROPHIC WIND SCALE
Contour heights at 60 metre intervals
Notes
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75°E
80°E
85°E
90°E
95°E


Station
Level
Date
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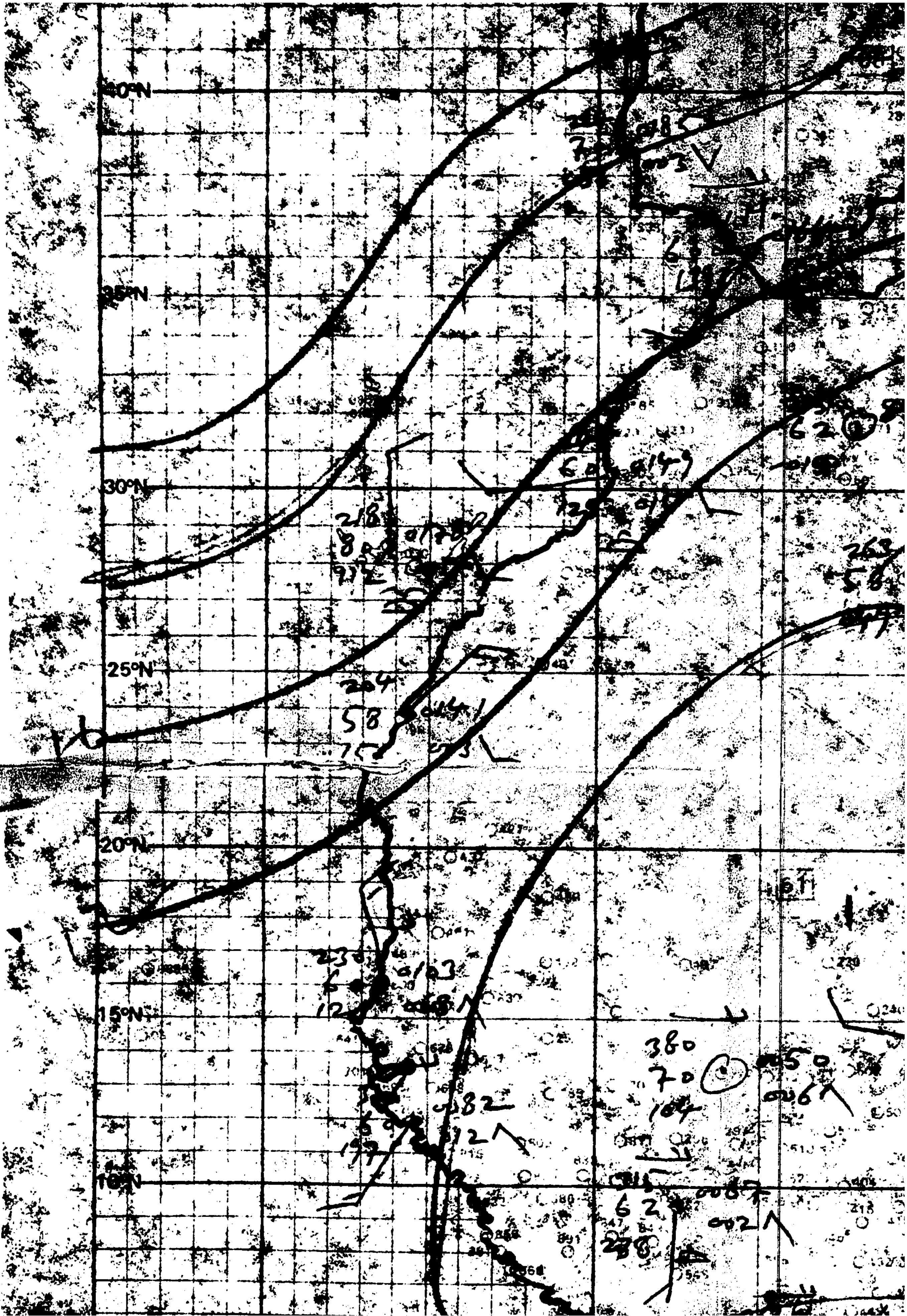
Plotted by
Drawn by
105°E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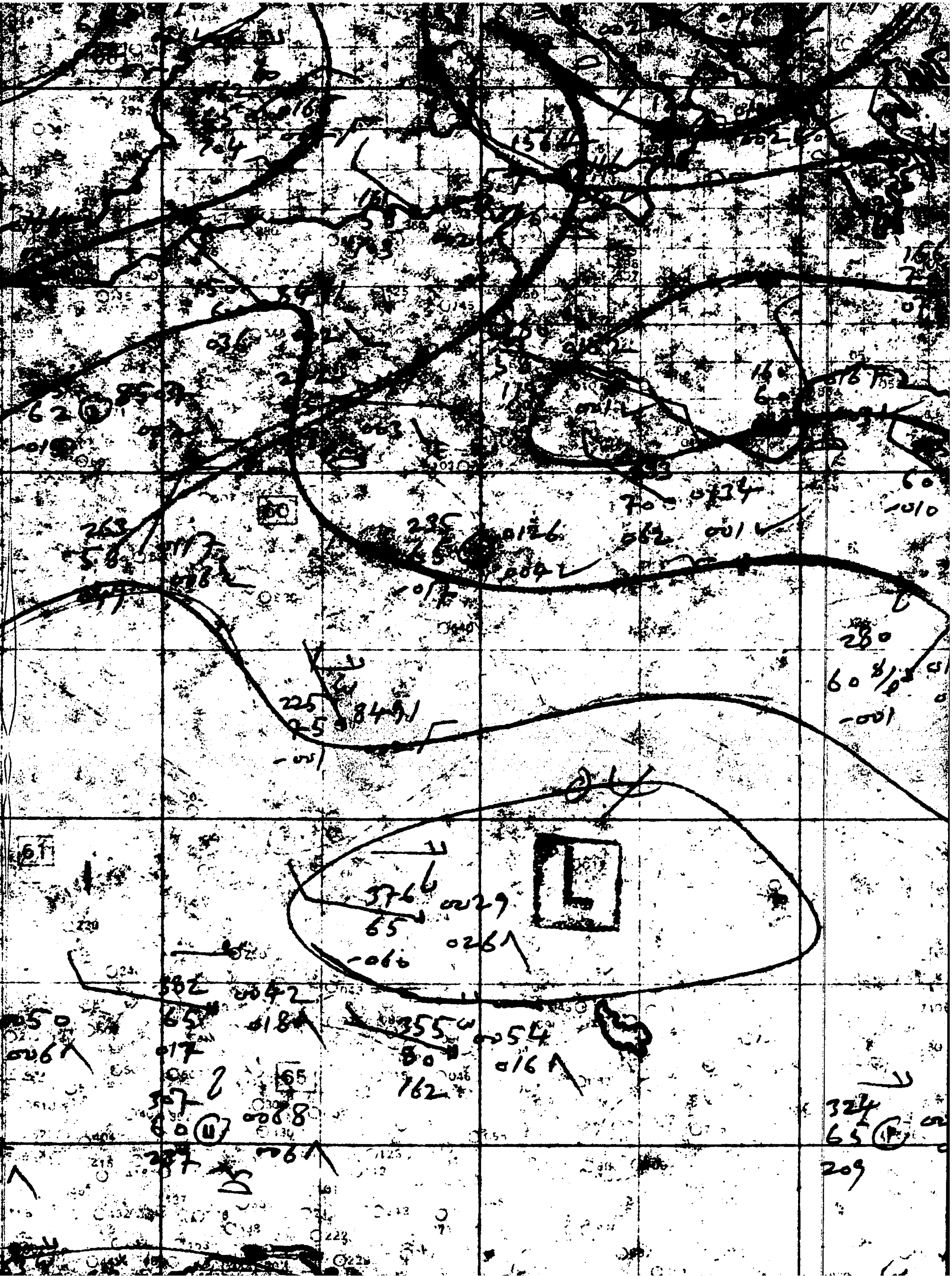
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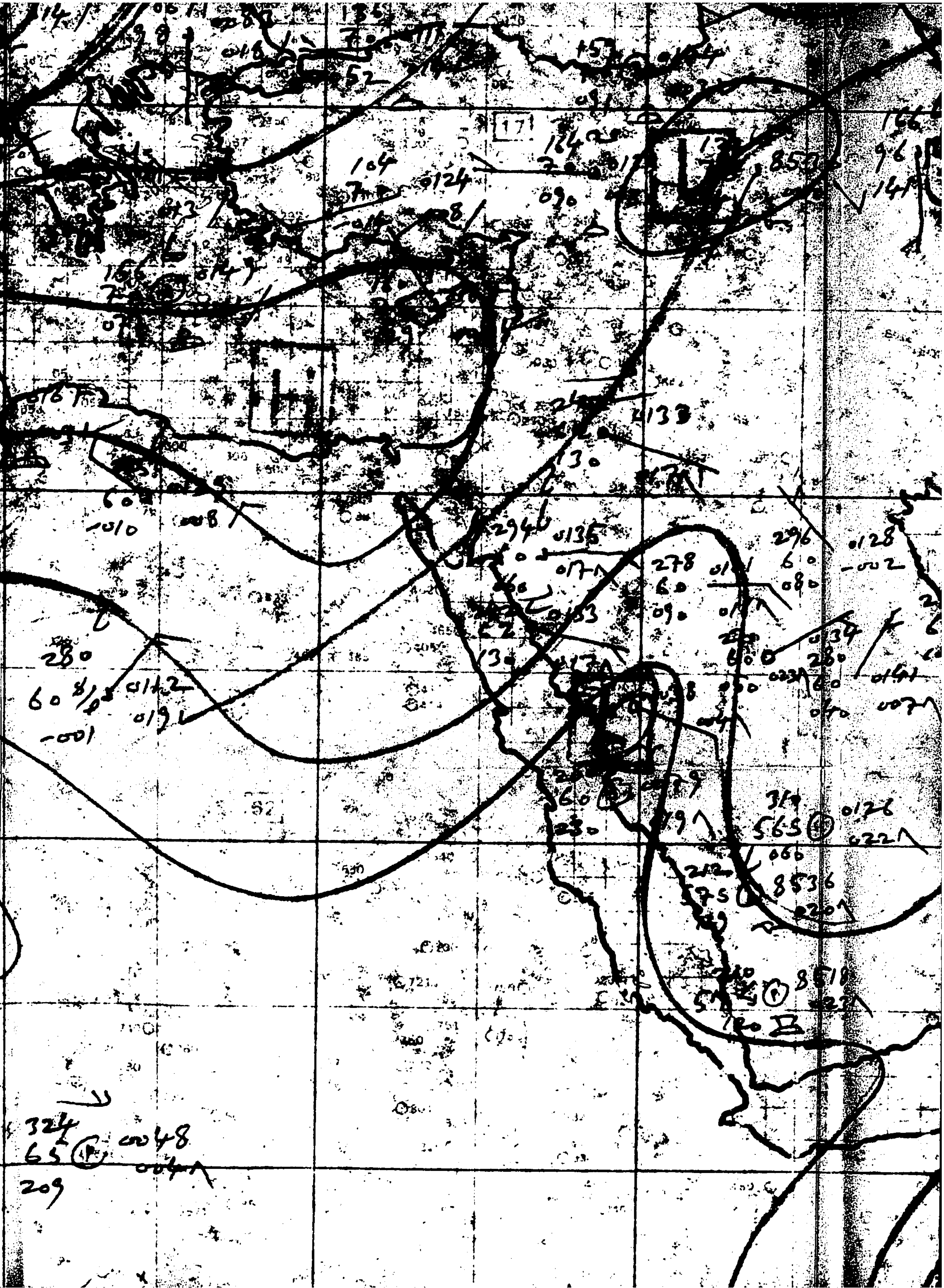

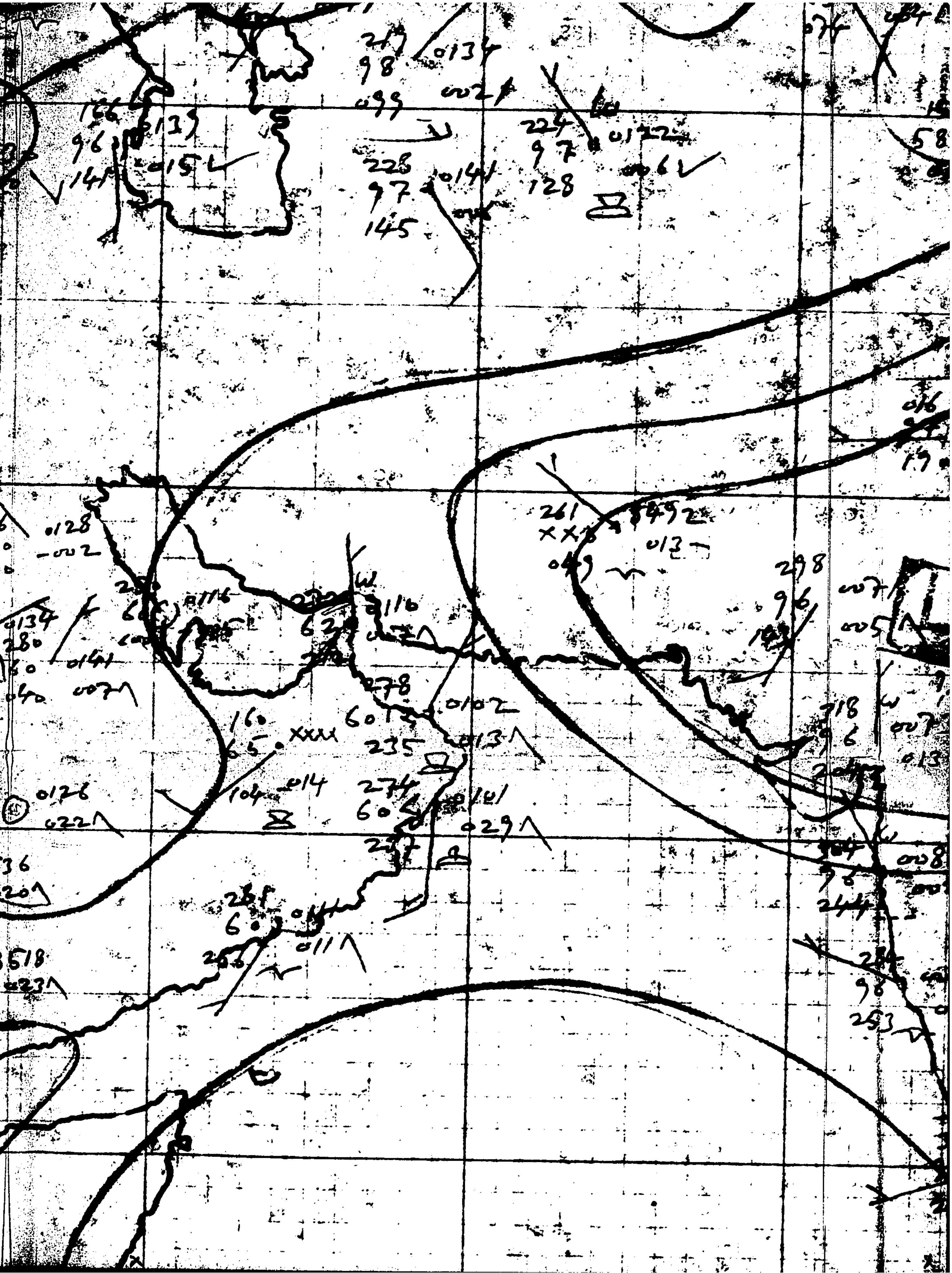

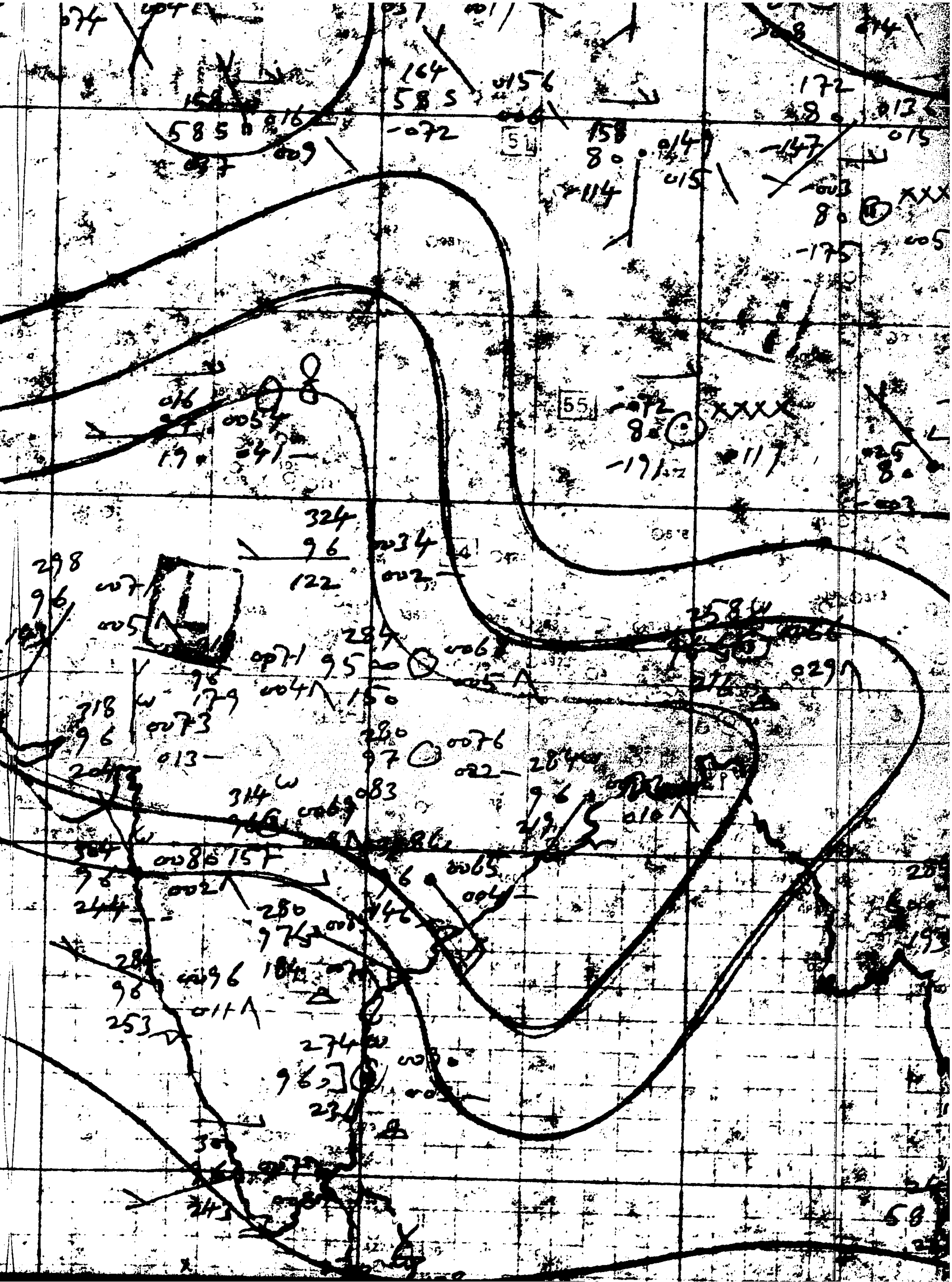
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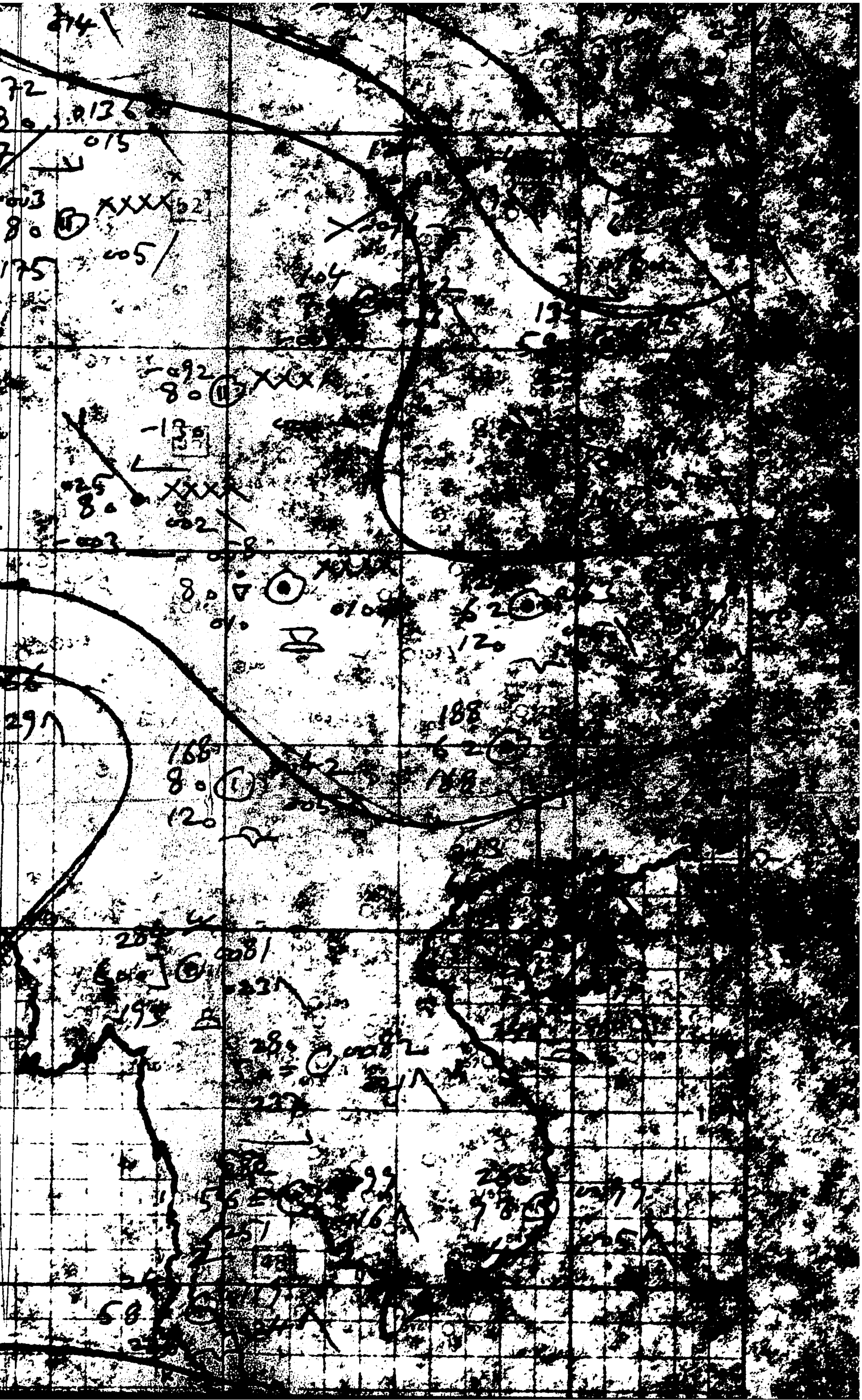

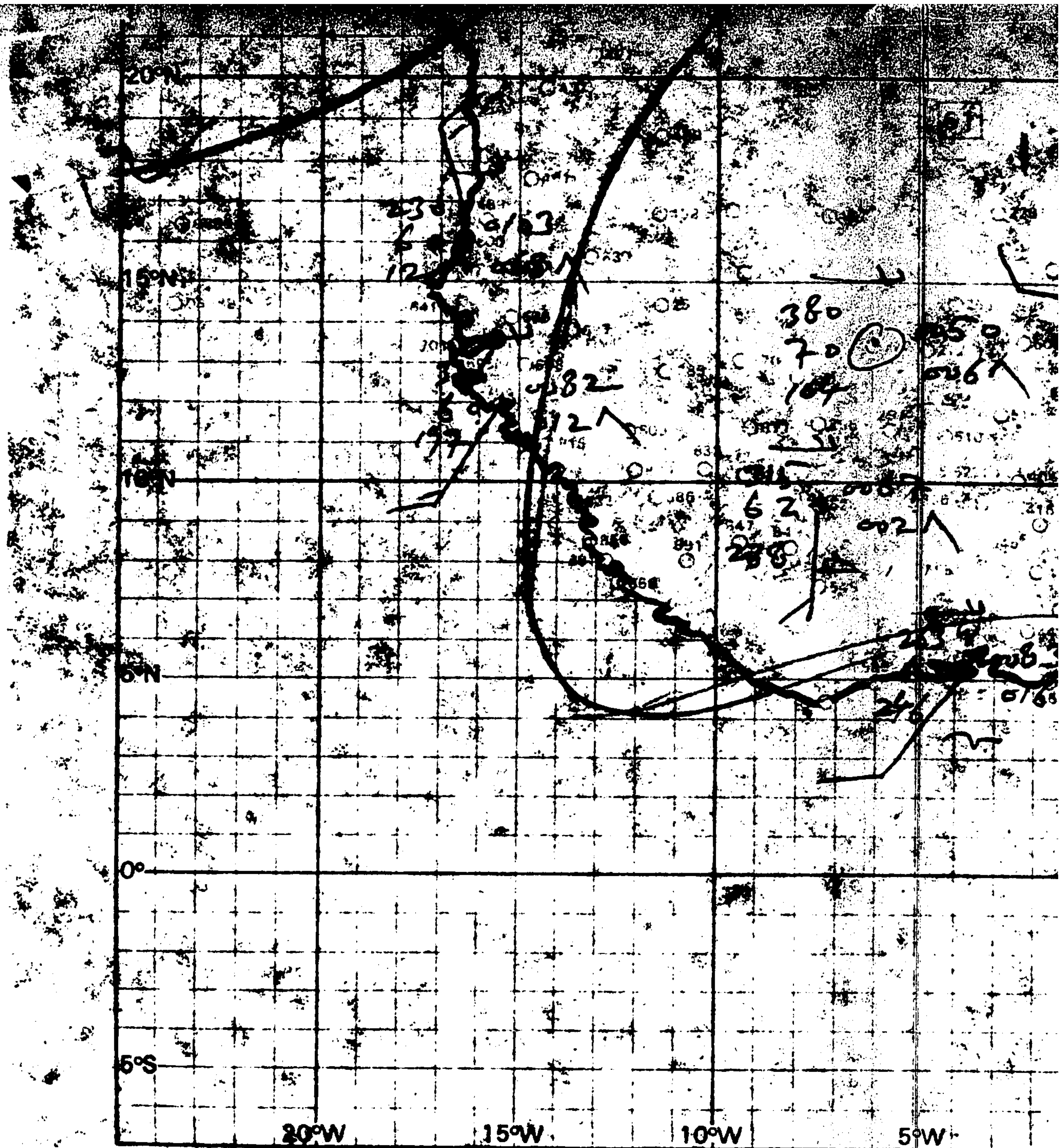

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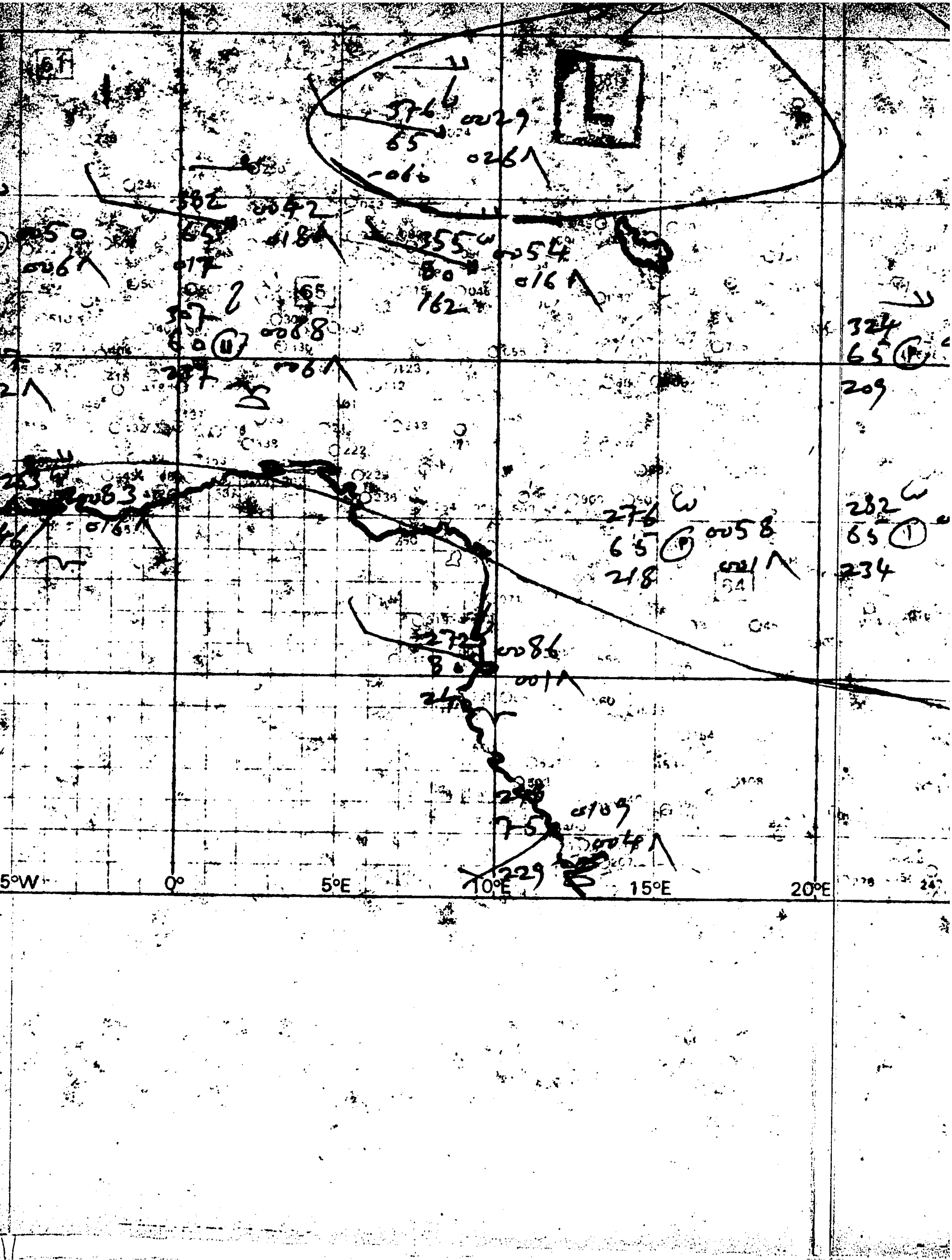
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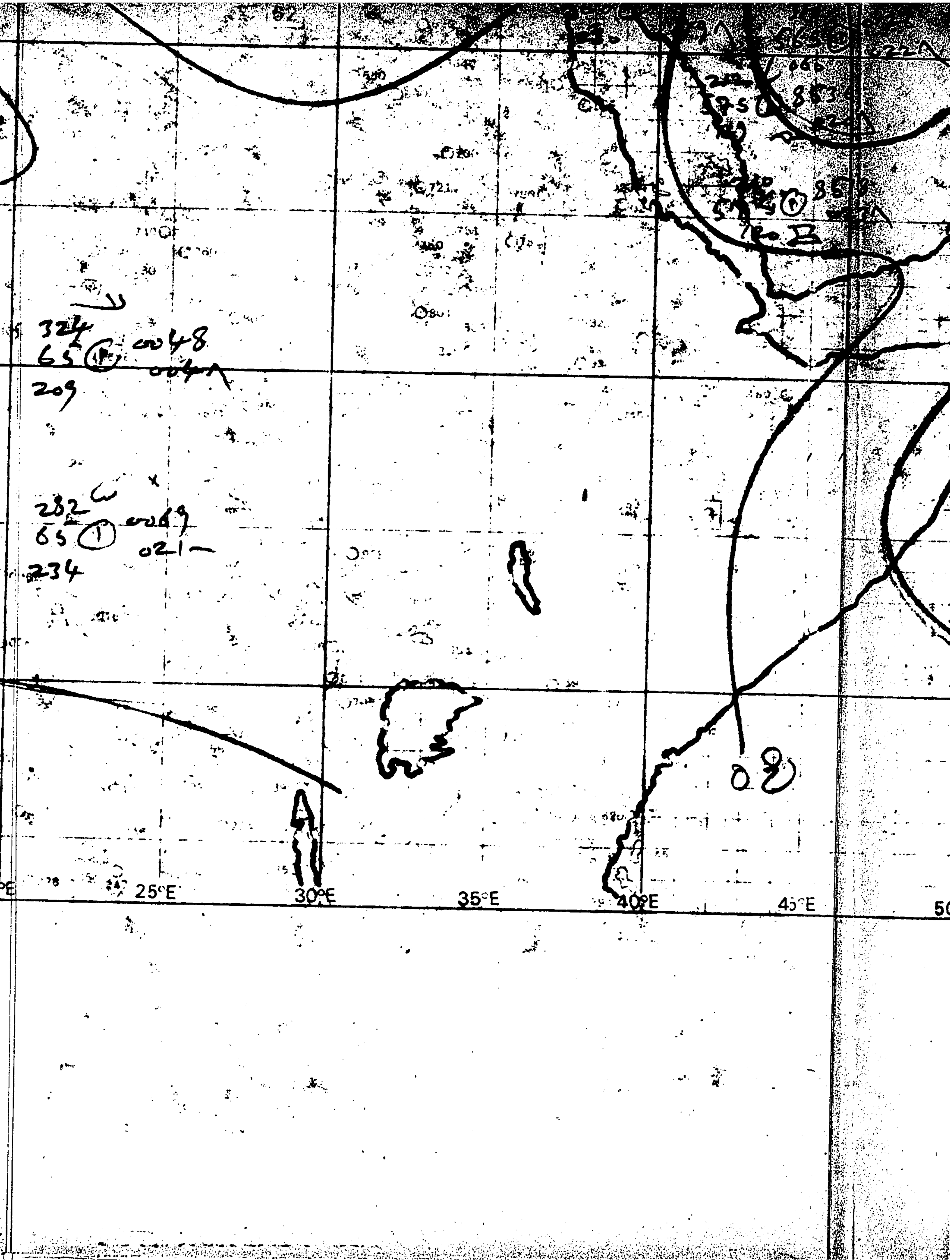

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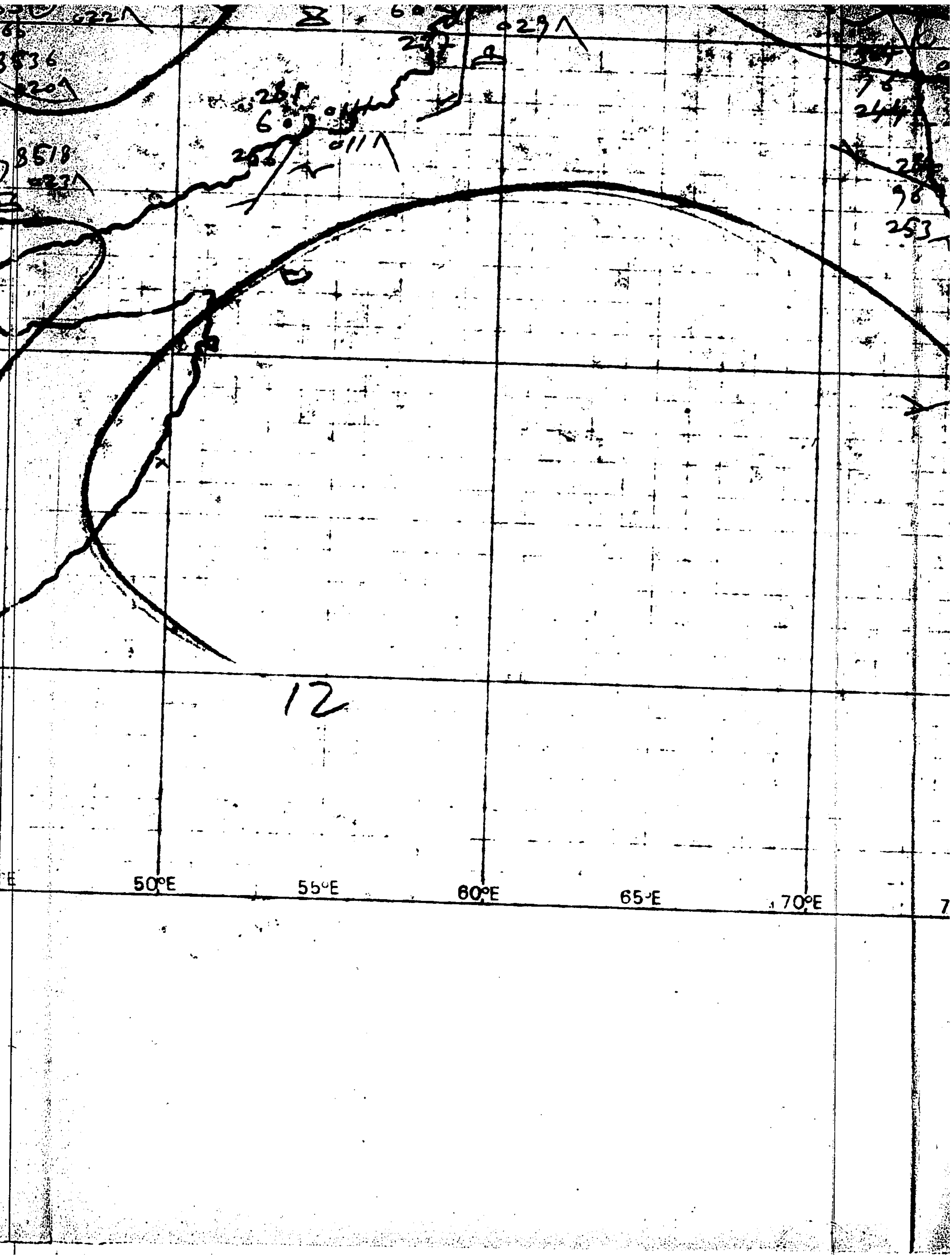

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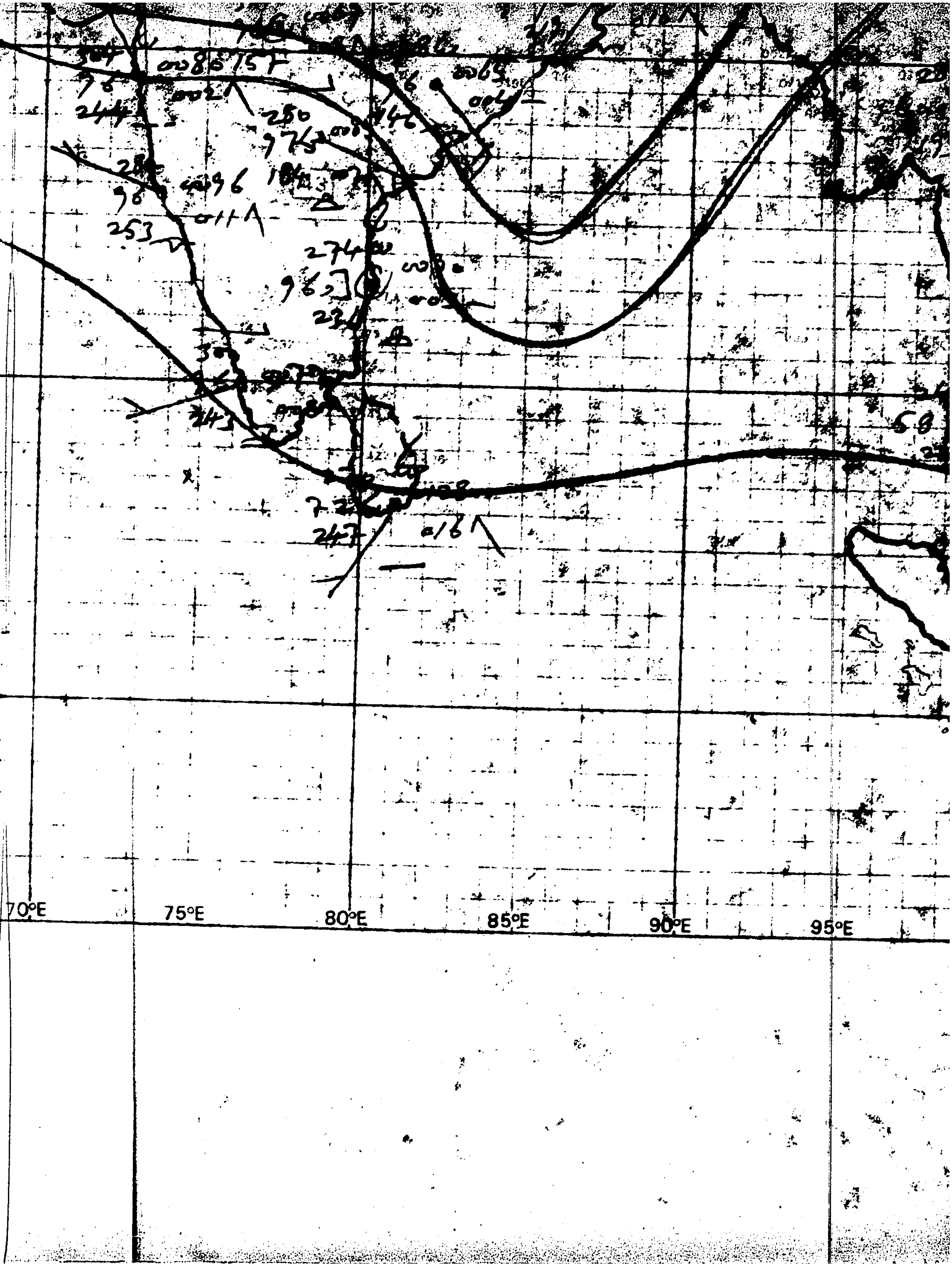
60°E
65°E
70°E
12
8
3536
3518
029
011


70°E
75°E
80°E
85°E
90°E
95°E

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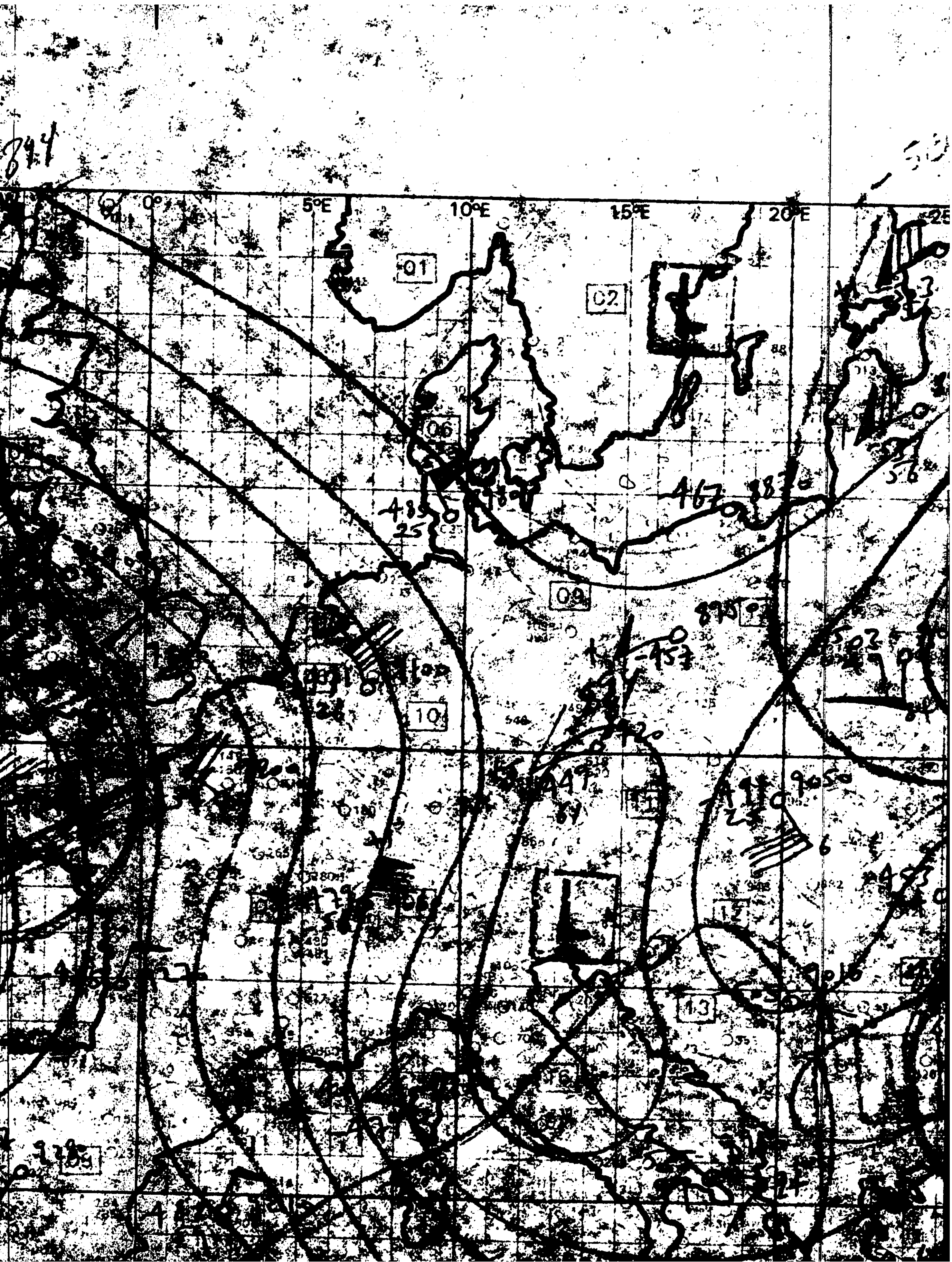
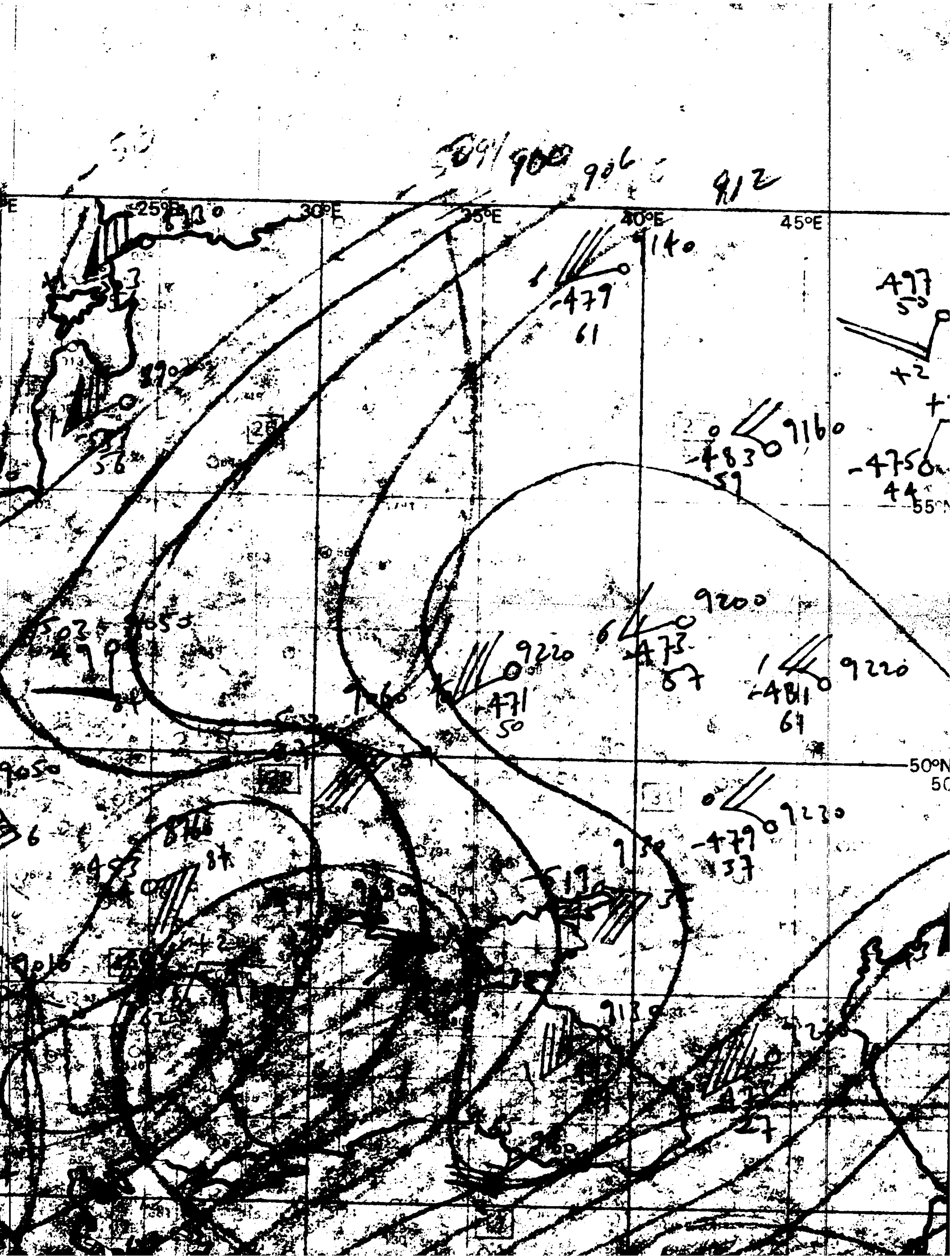
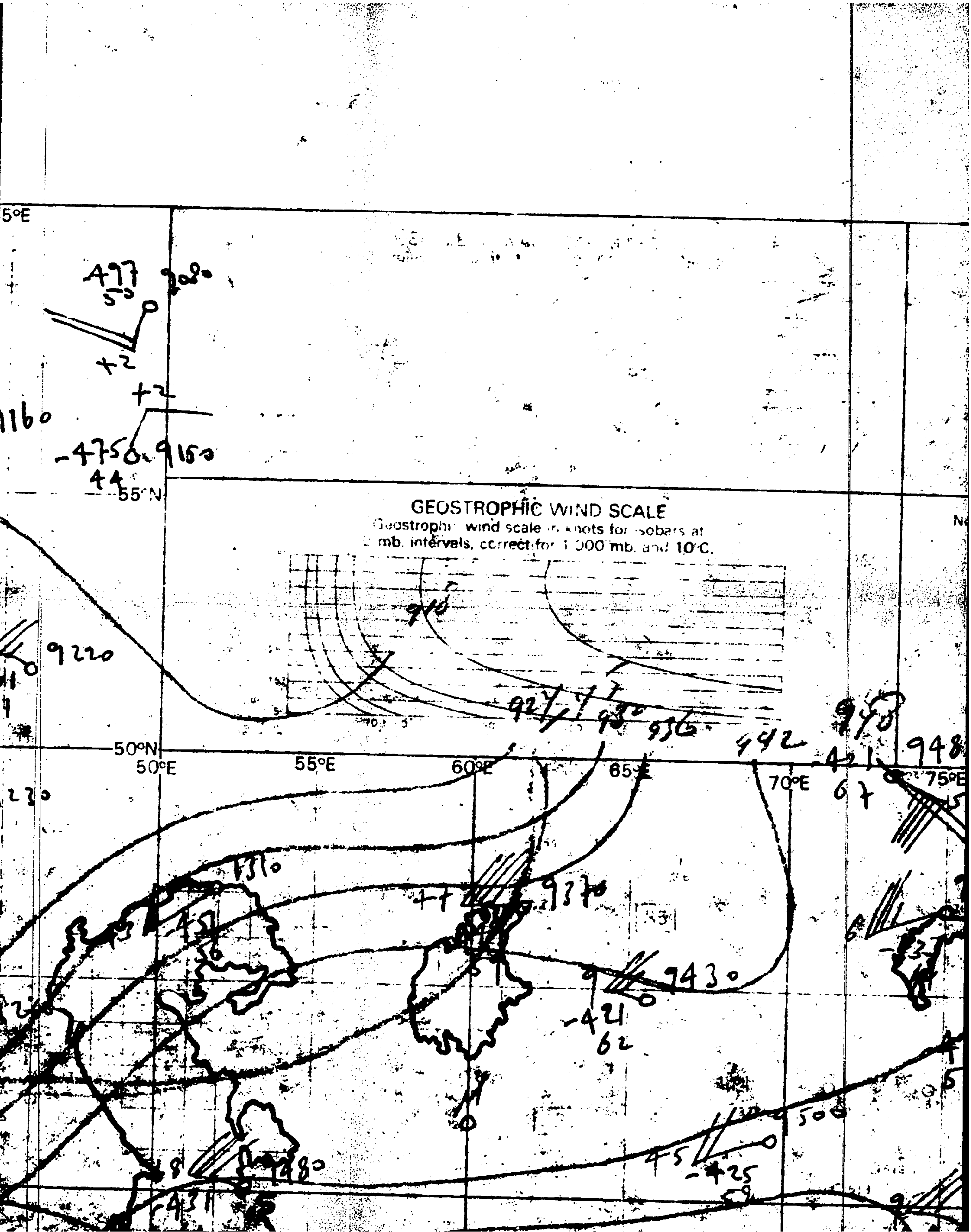

0°
5°E
10°E
15°E
20°E
01
02
06
09
10
12
13
L

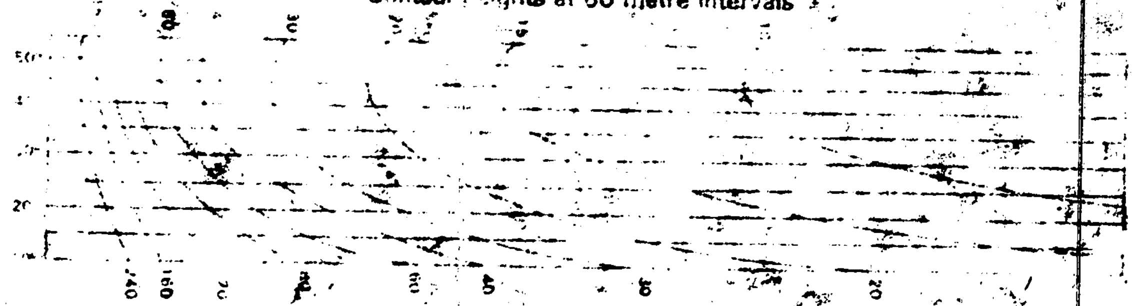


25°E
30°E
35°E
40°E
45°E
55°N
50°N



GEOSTROPHIC WIND SCALE
wind scale
knots for
mb. intervals, correct for
mb. and 10°C.
55°N
50°N
50°E
55°E
60°E
65°E
70°E
75°E

GEOSTROPHIC WIND SCALE
Contour heights at 60 metre intervals



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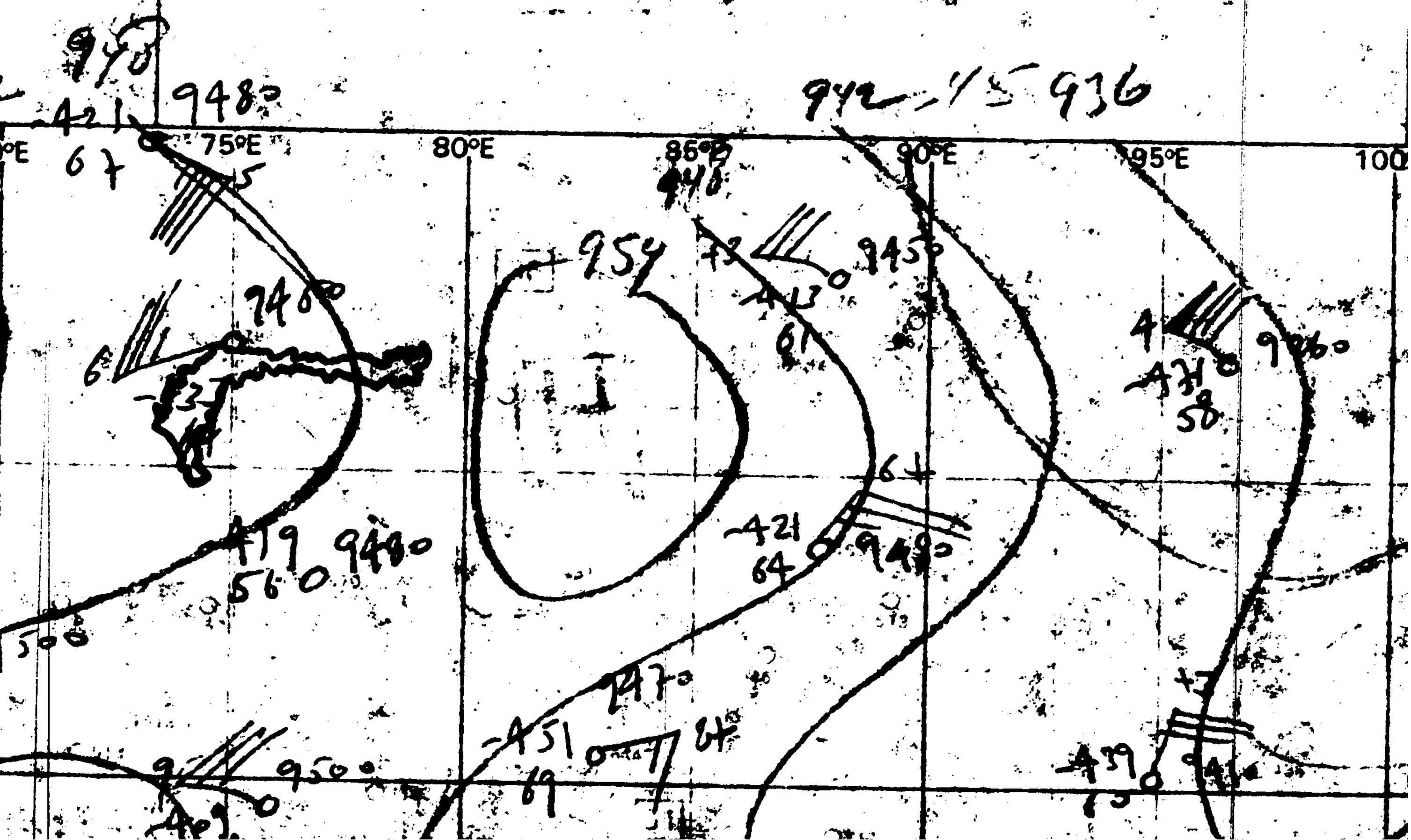

75°E
80°E
85°E
90°E
95°E
954

المملكة العربية السعودية

وزارة الدفاع والطيران

ND SCALE

etre intervals

Station

Level

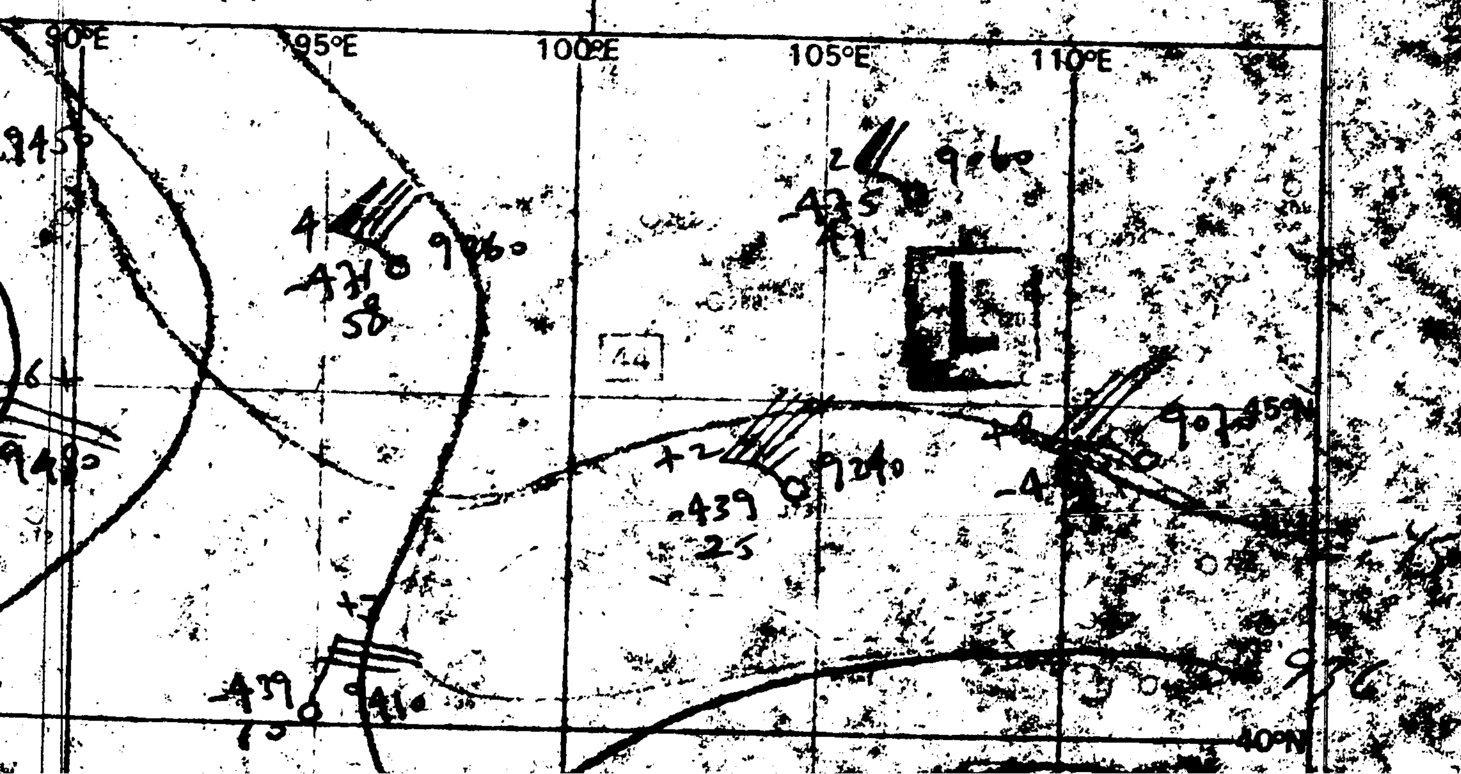
Date

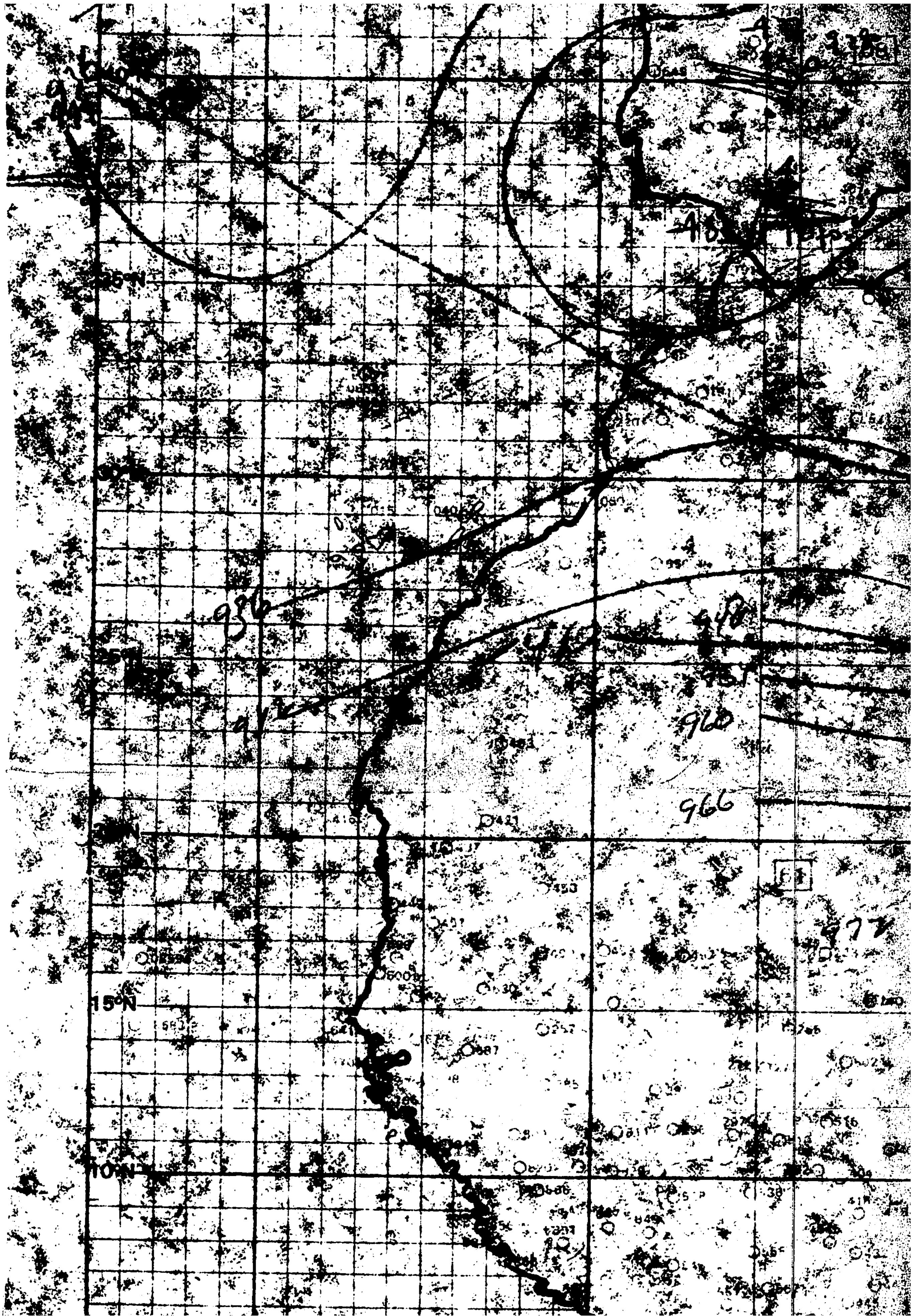
Time

Plotted by

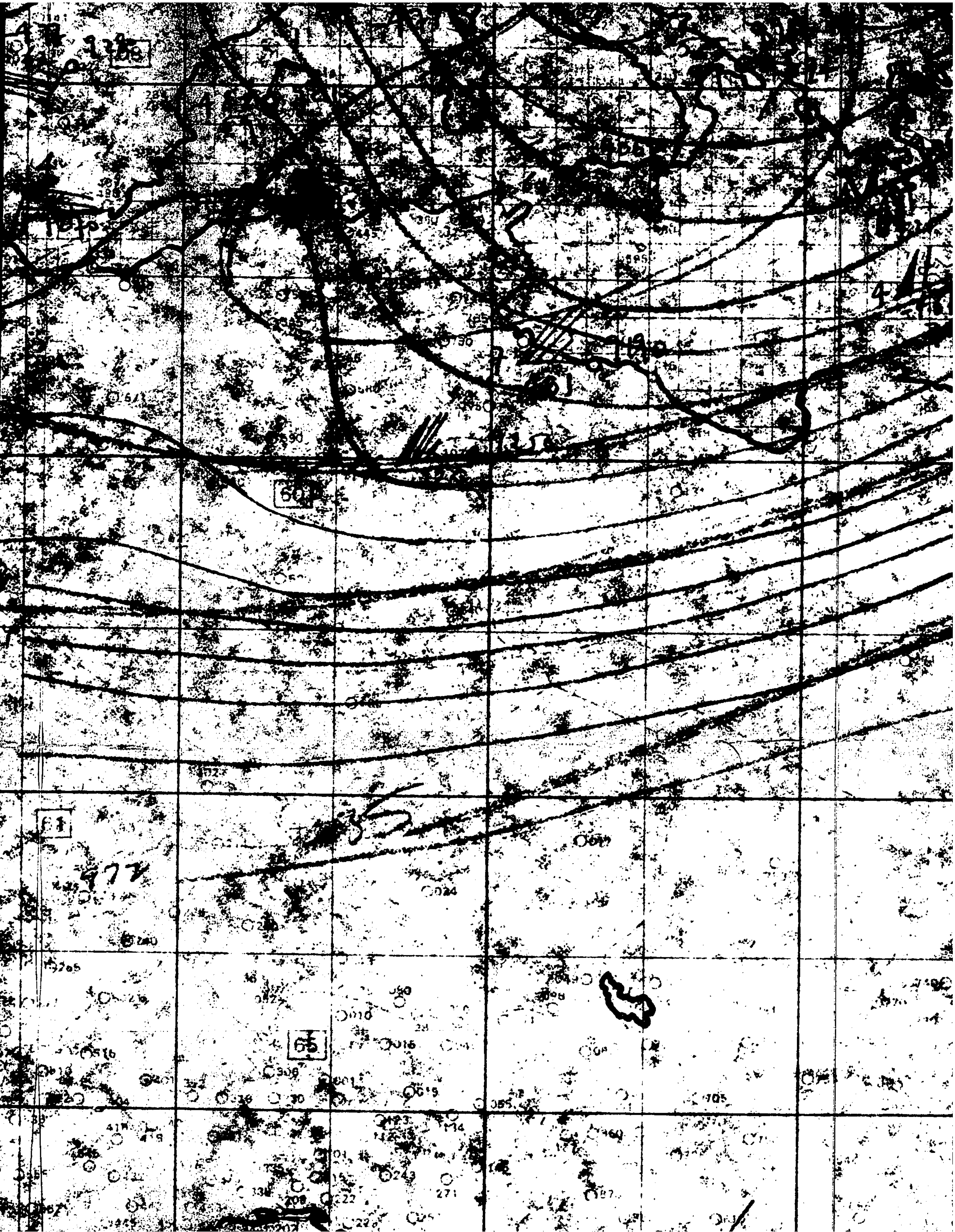
Drawn by

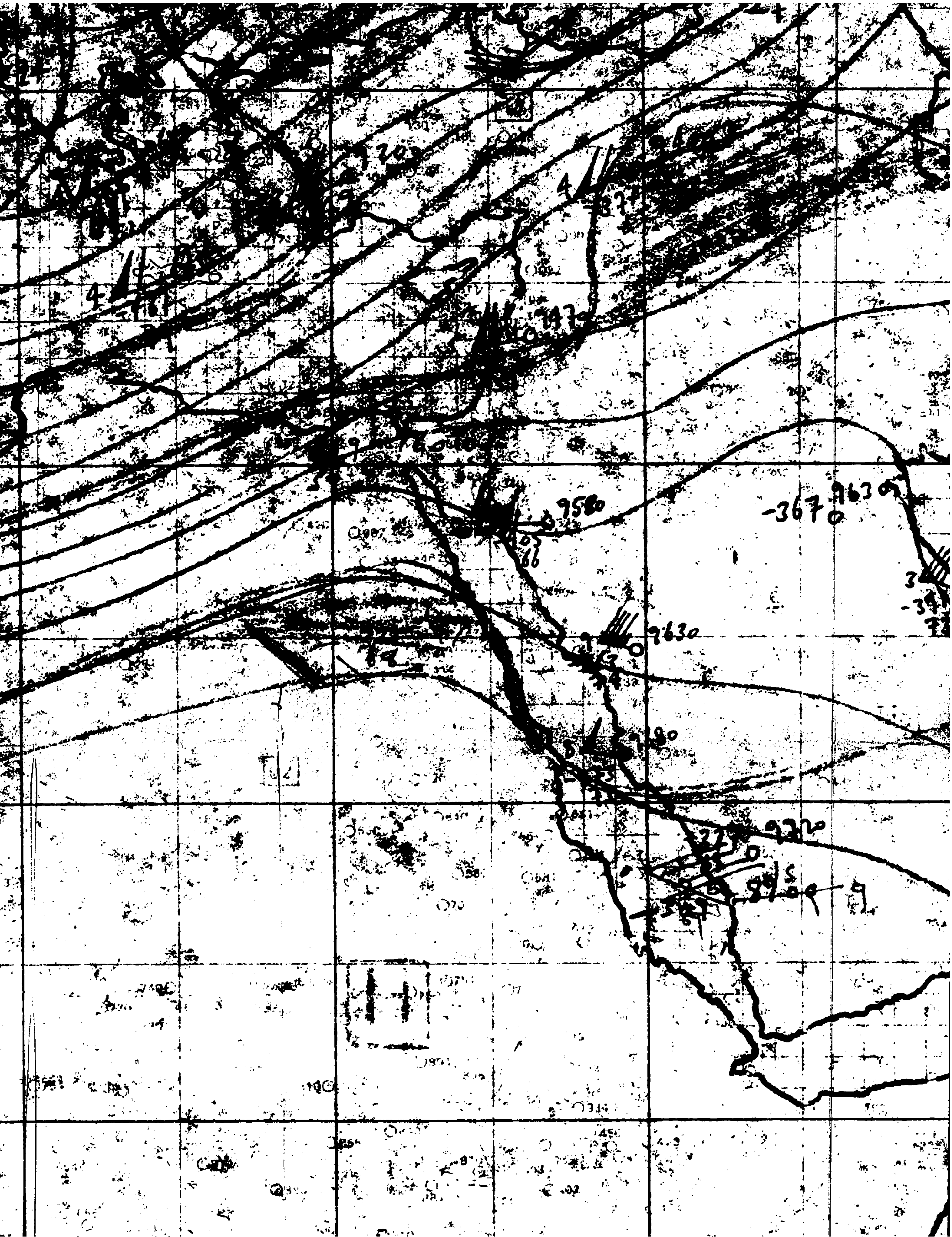
-/5 936

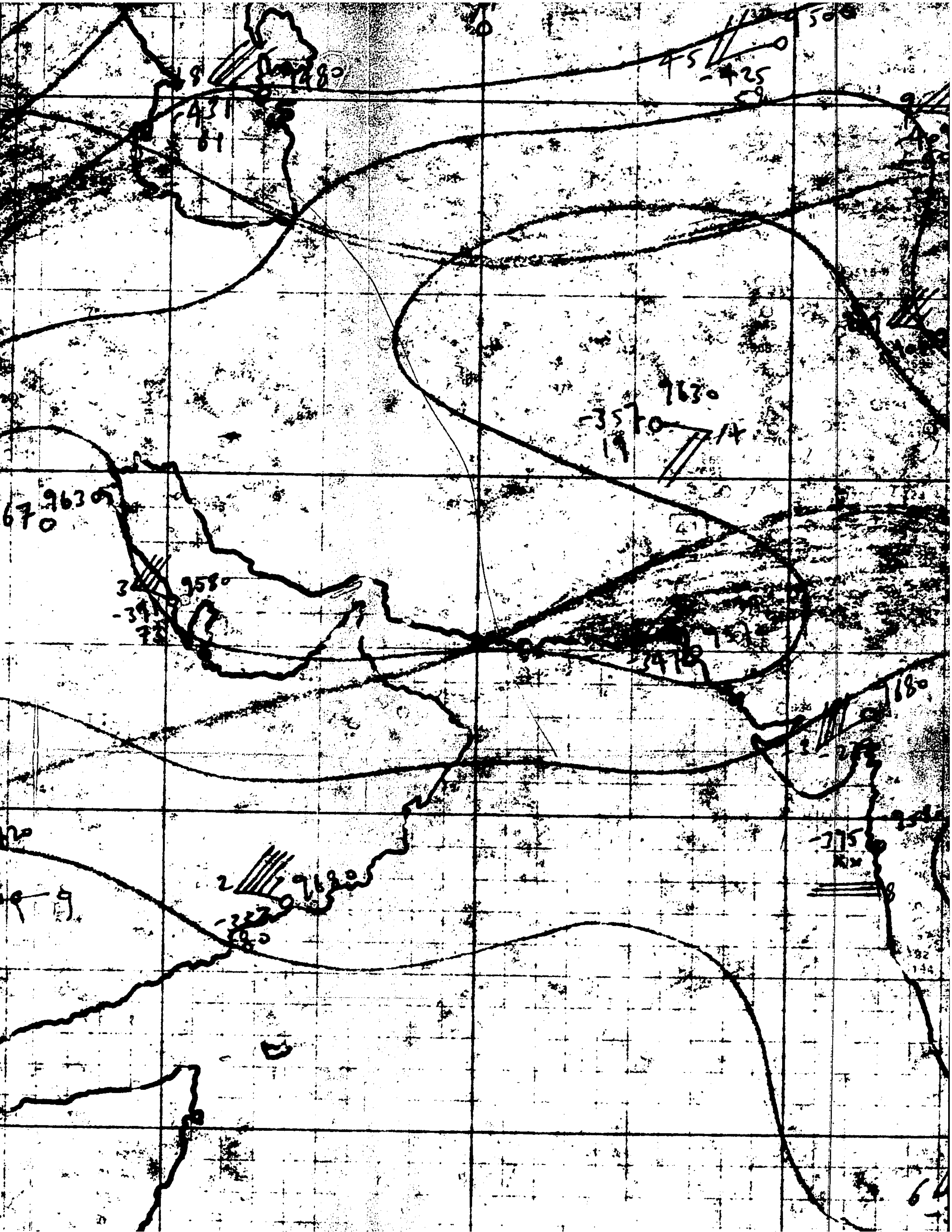


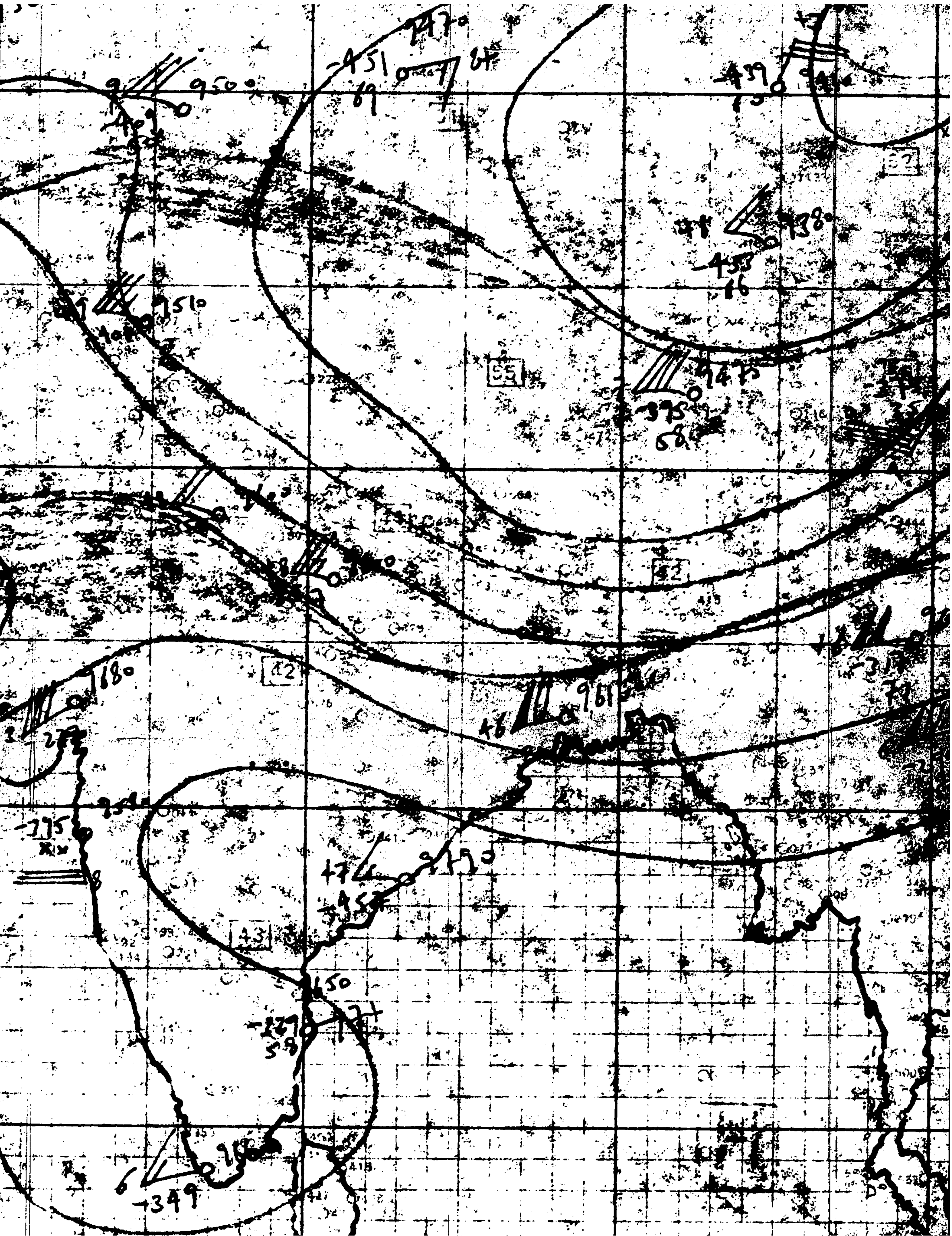


936
966
15°N
10°N

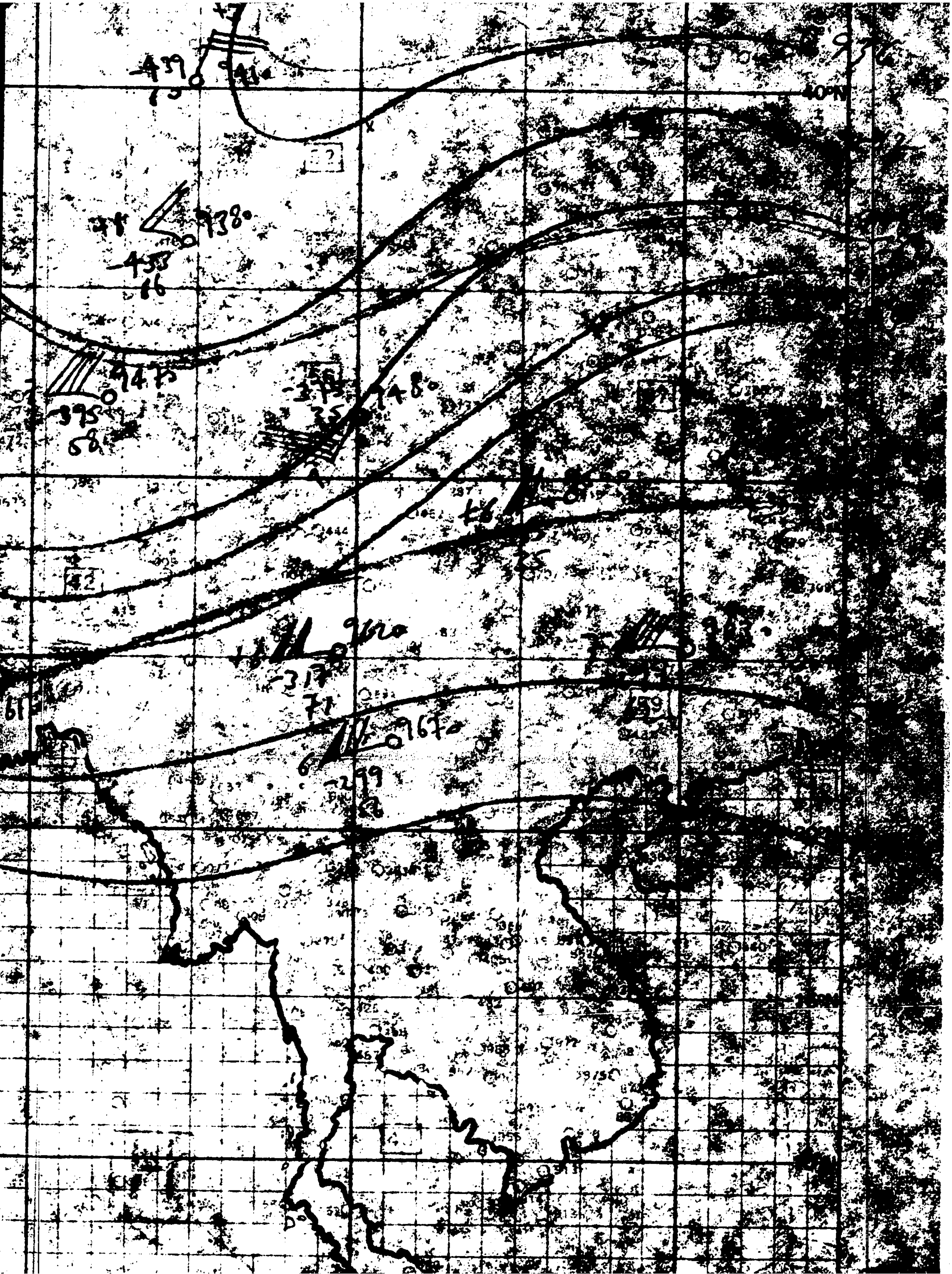


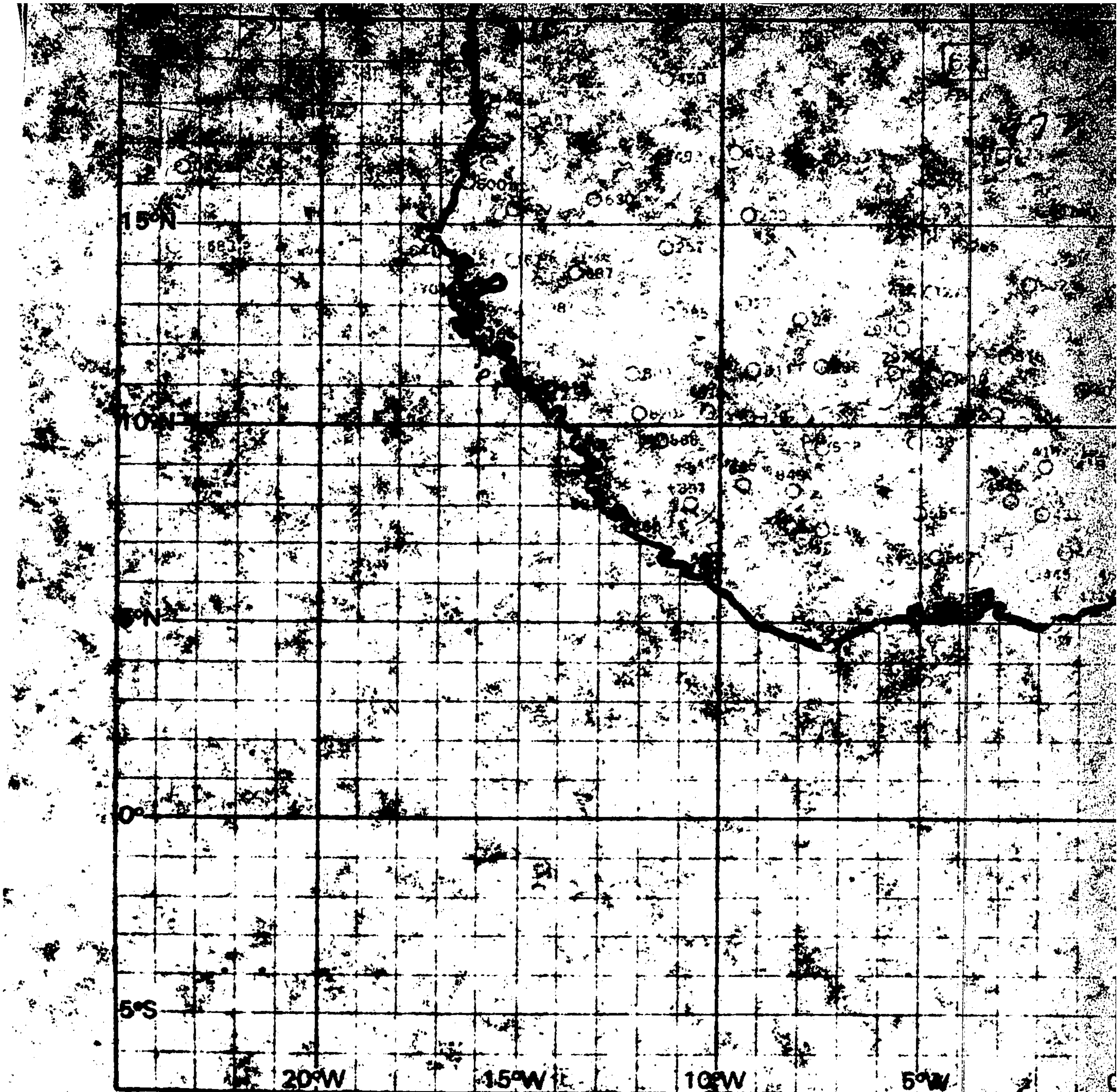

9580
-367
9630



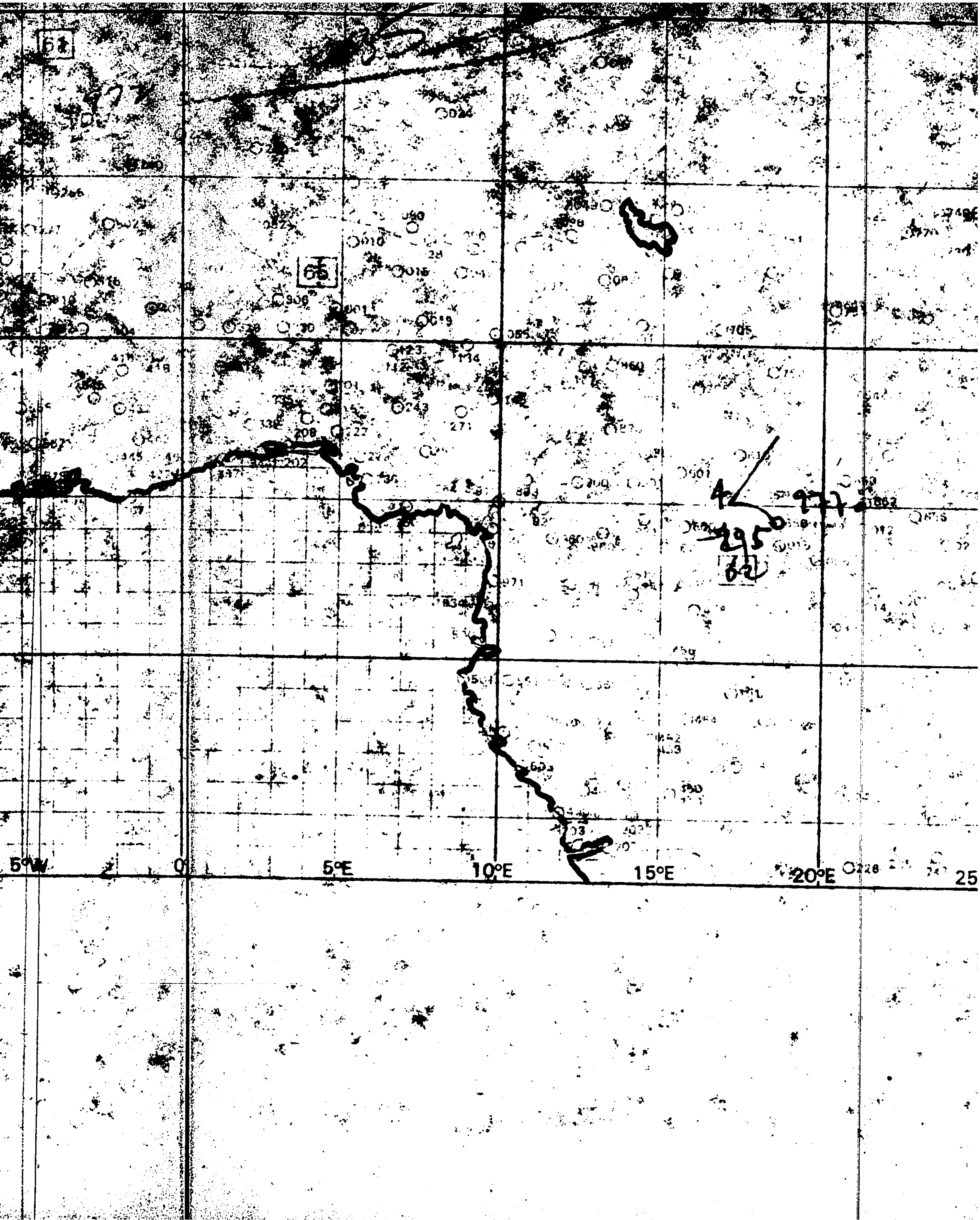


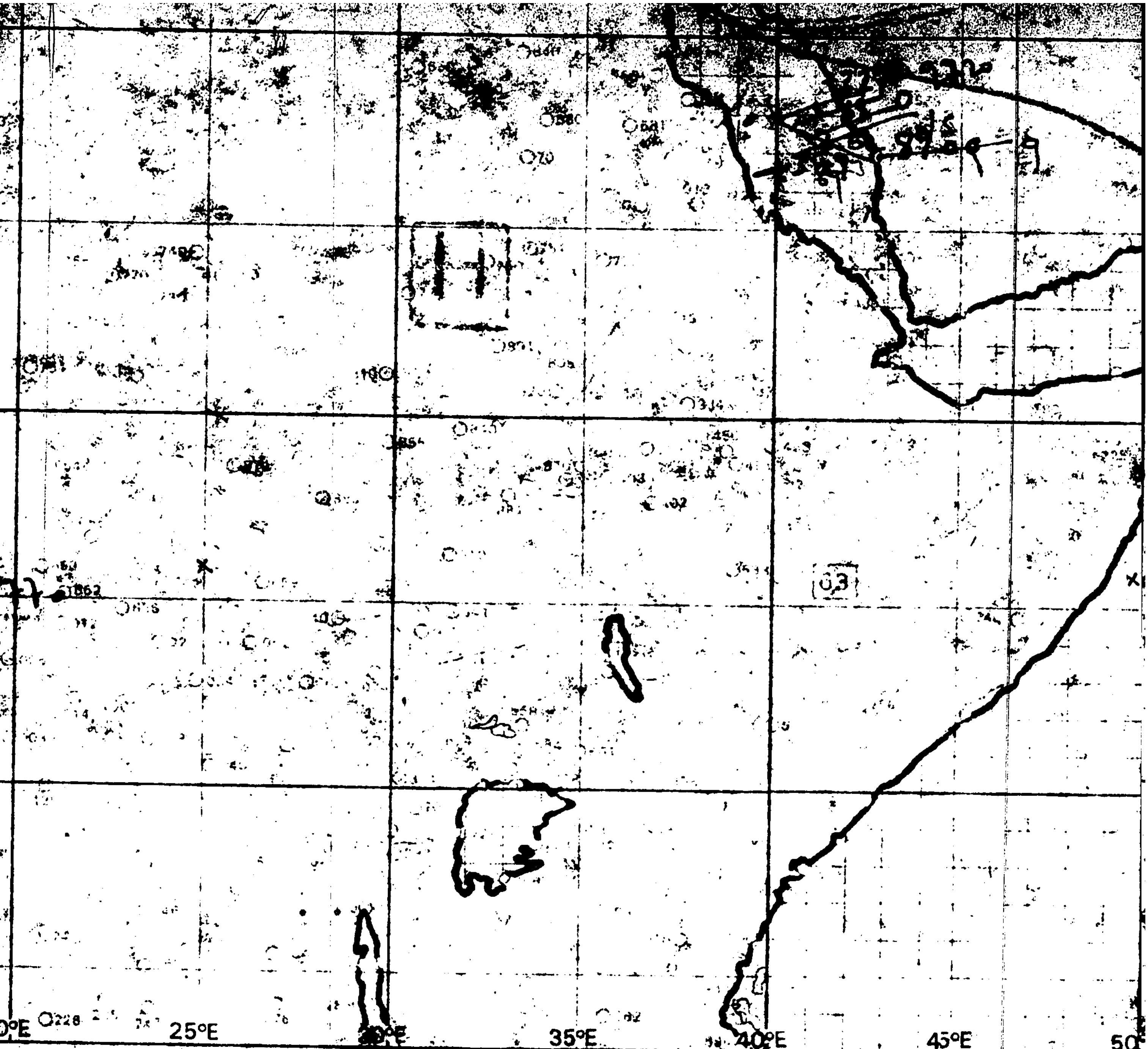
55
42
12
43



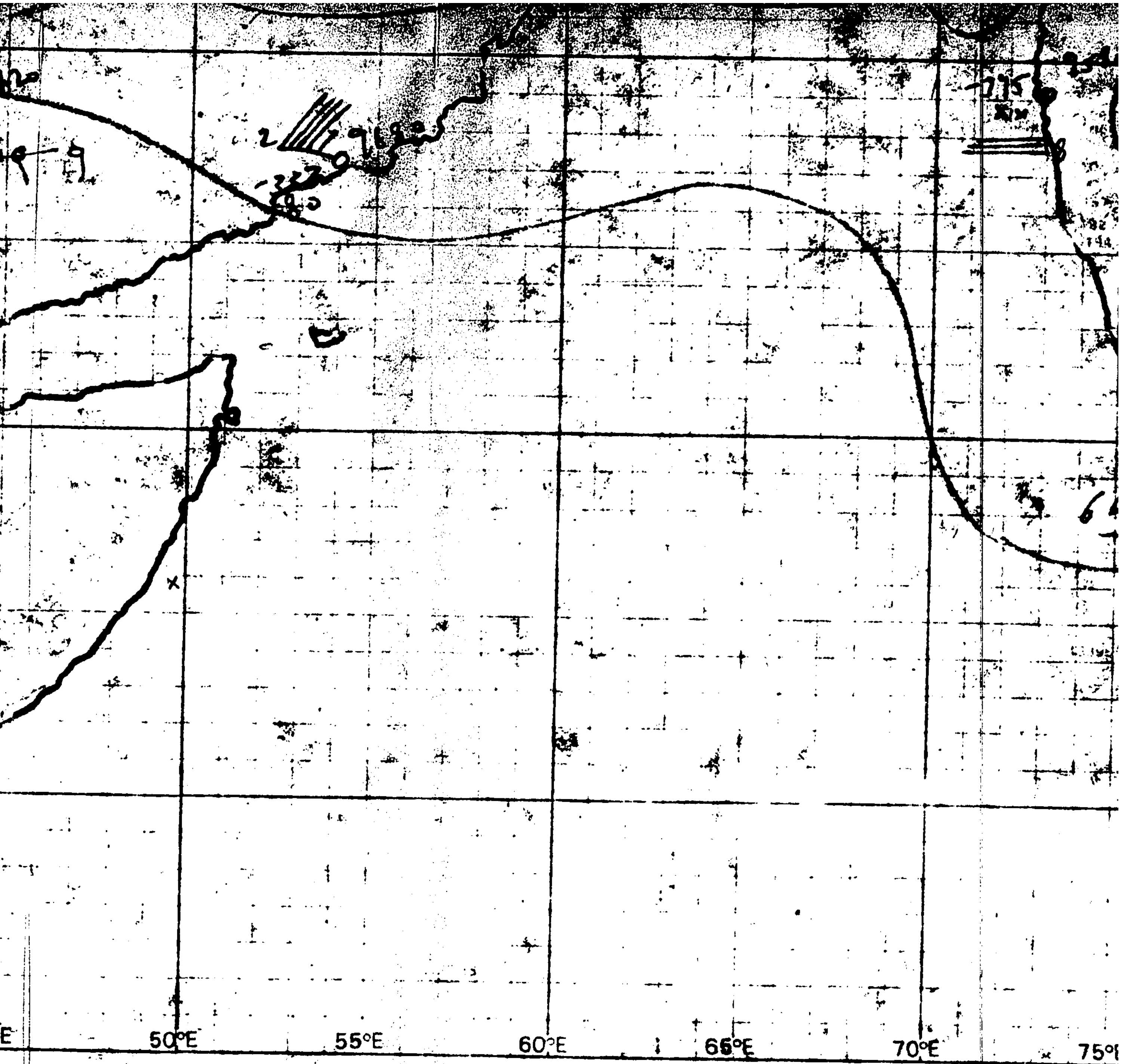


نموذج ا . ح معدل ٩٩/٥٠٠٤

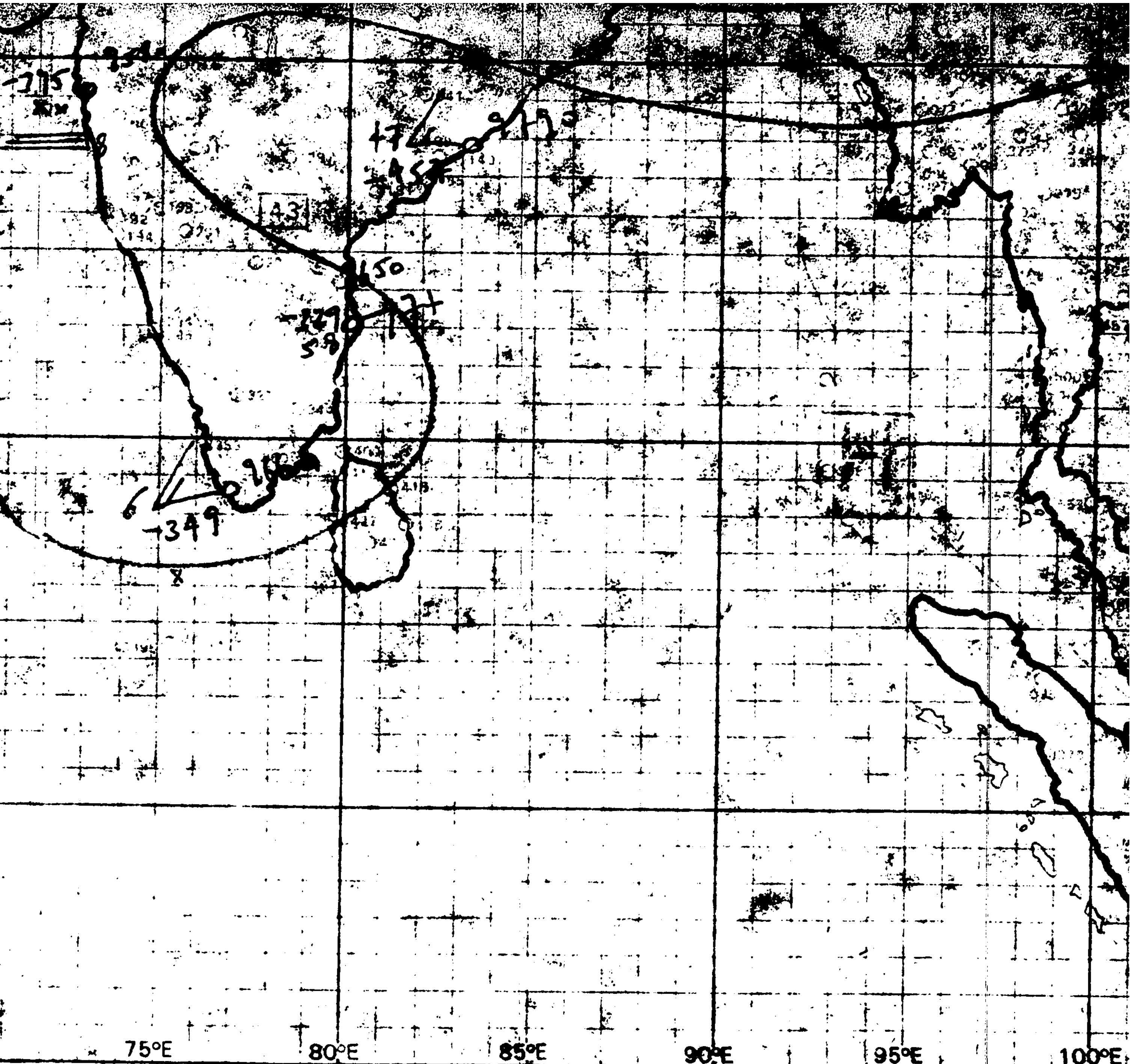

5°W
0°
5°E
10°E
15°E
20°E
25

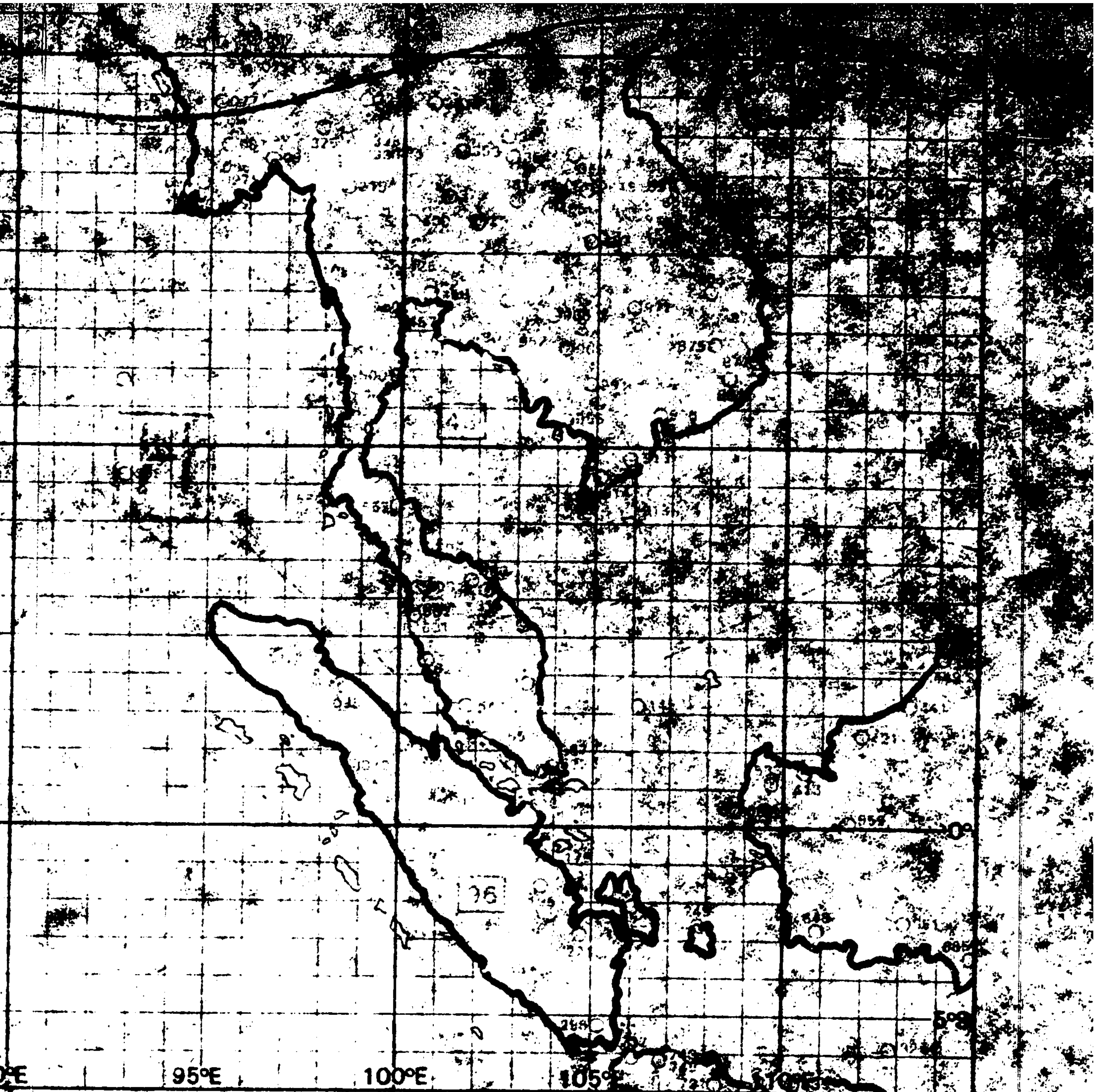


25°E
30°E
35°E
40°E
45°E



50°E
55°E
60°E
65°E
70°E


75°E
80°E
85°E
90°E
95°E
100°E



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APPENDIX B

1. Surface Map
2. Surface Map (analyzed)
3. Upper Air Map

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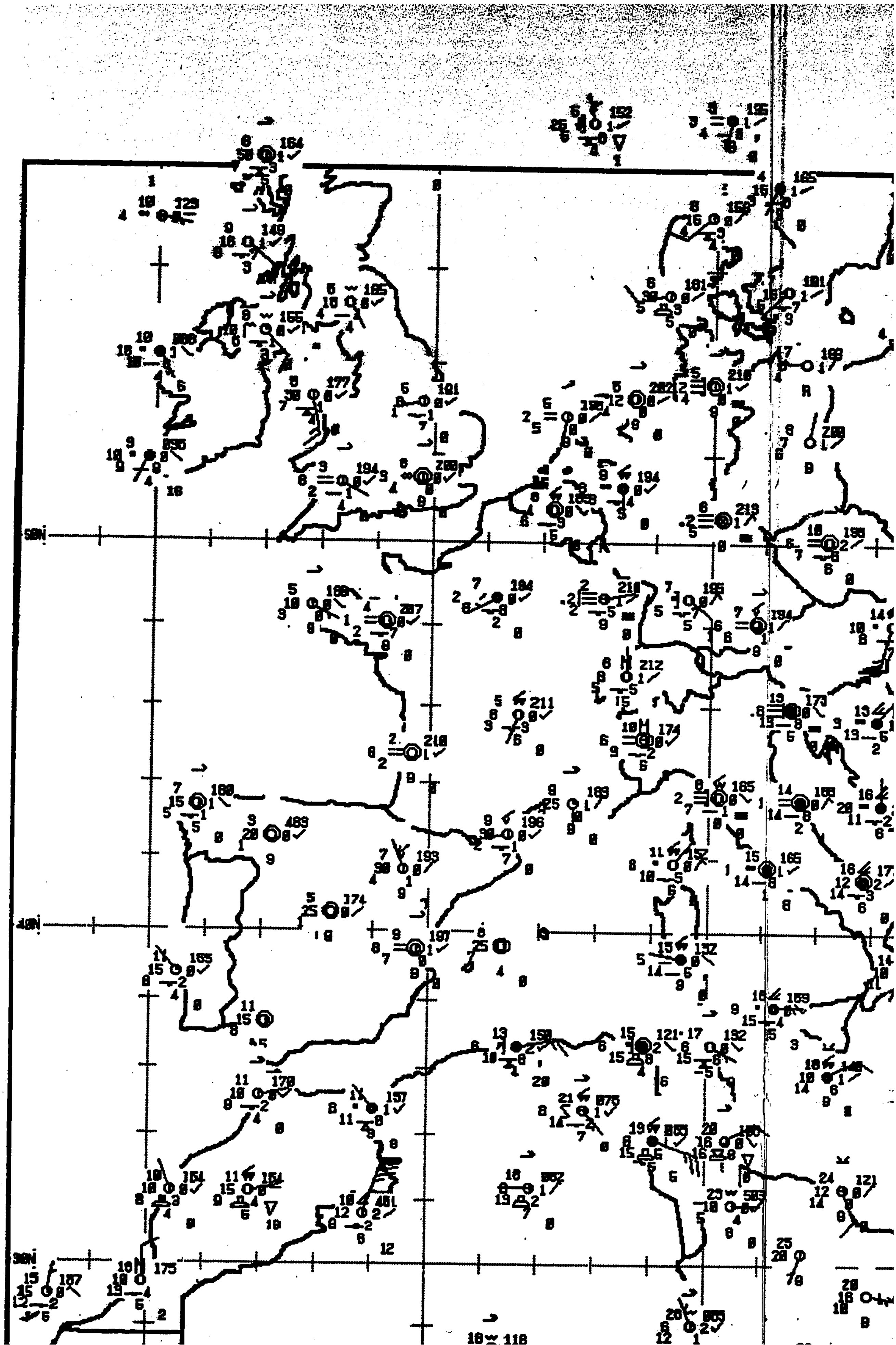
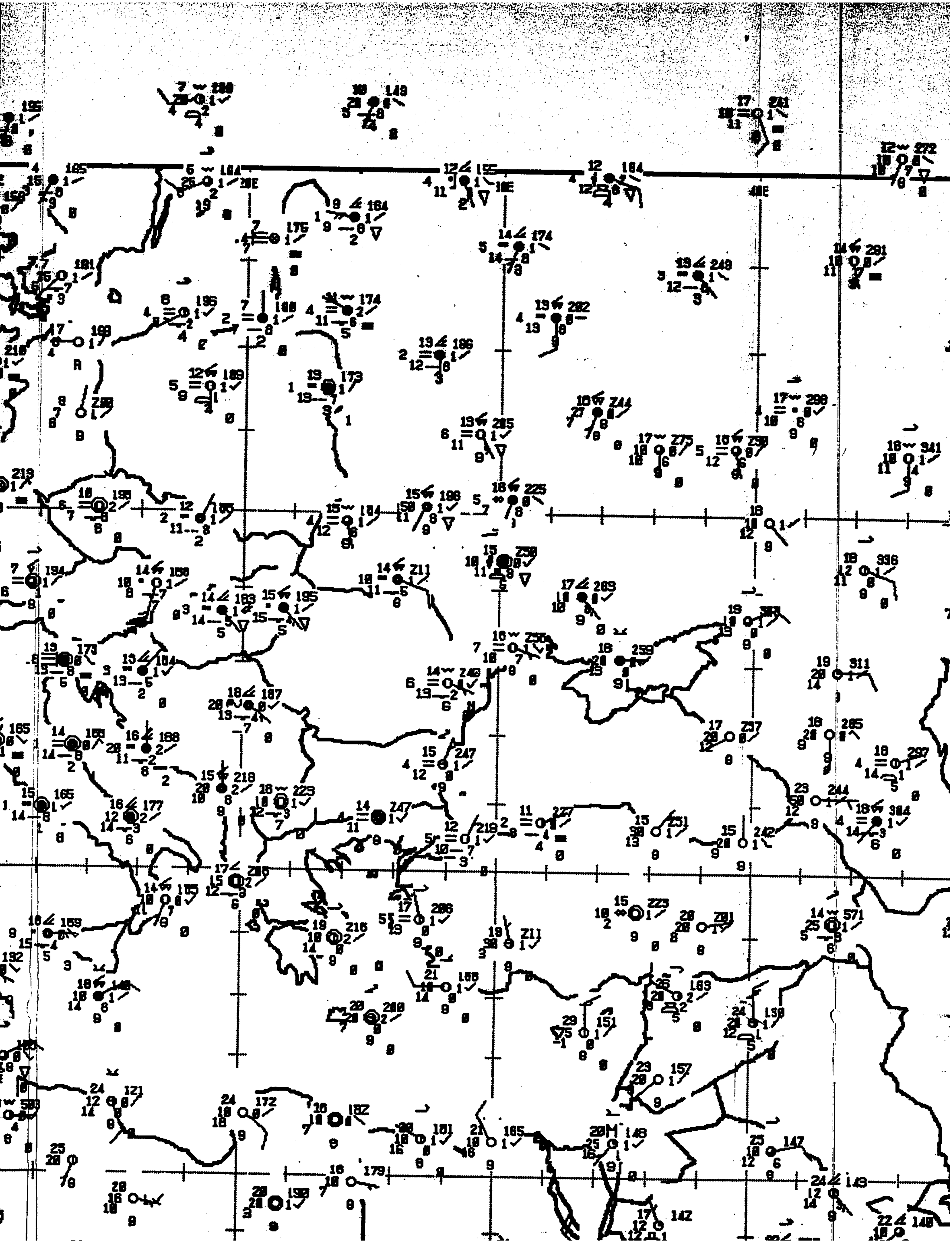
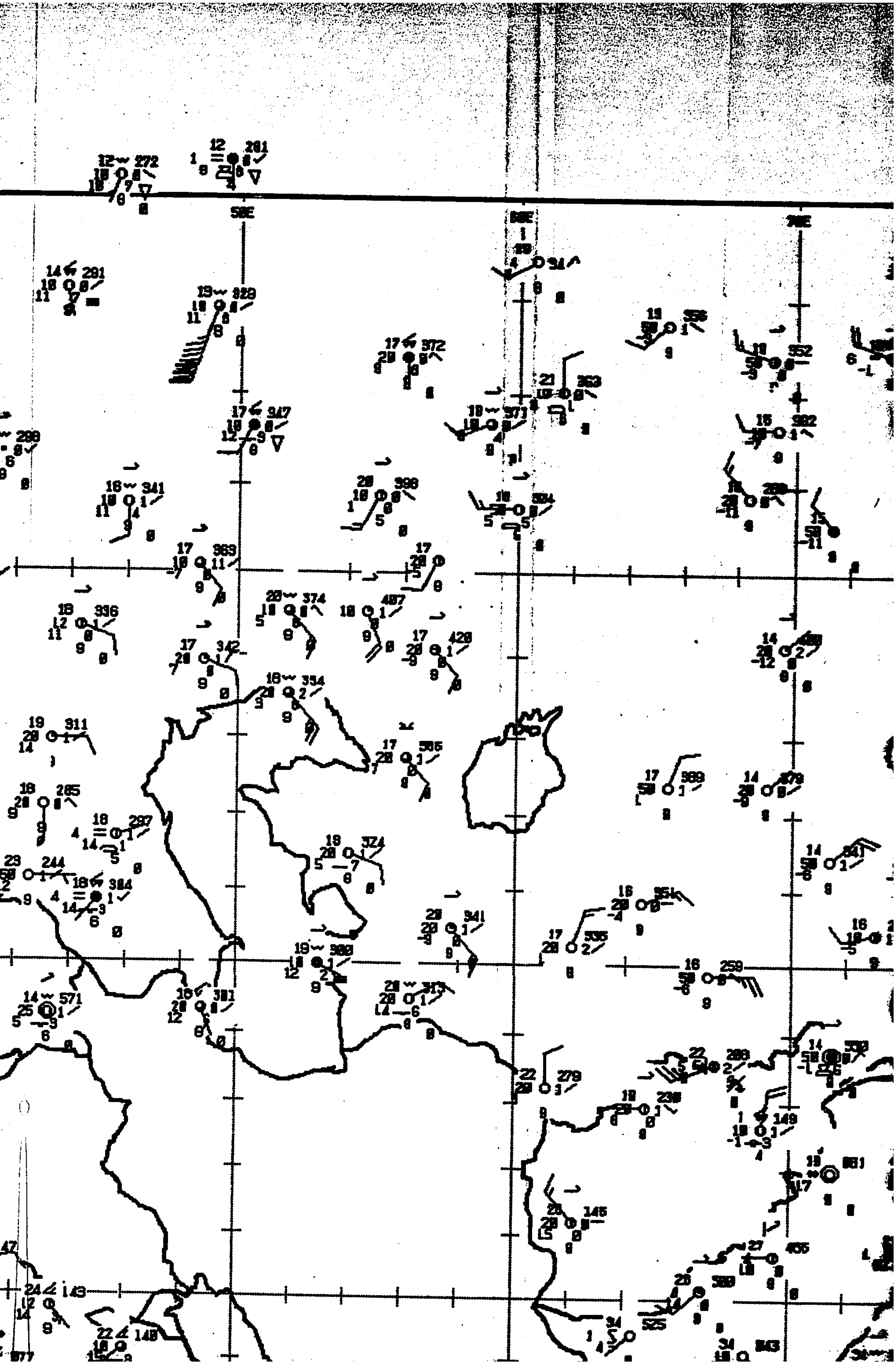
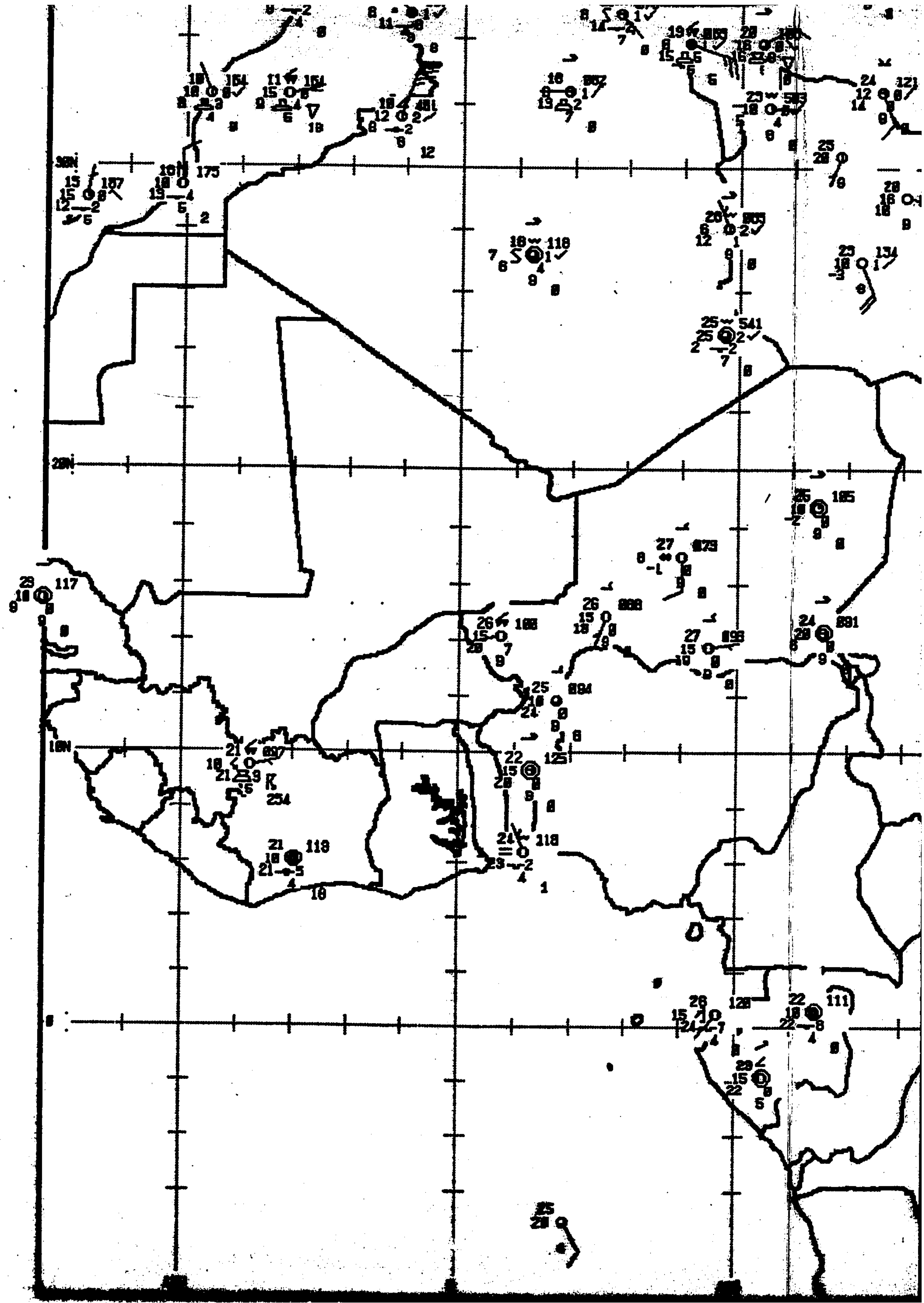
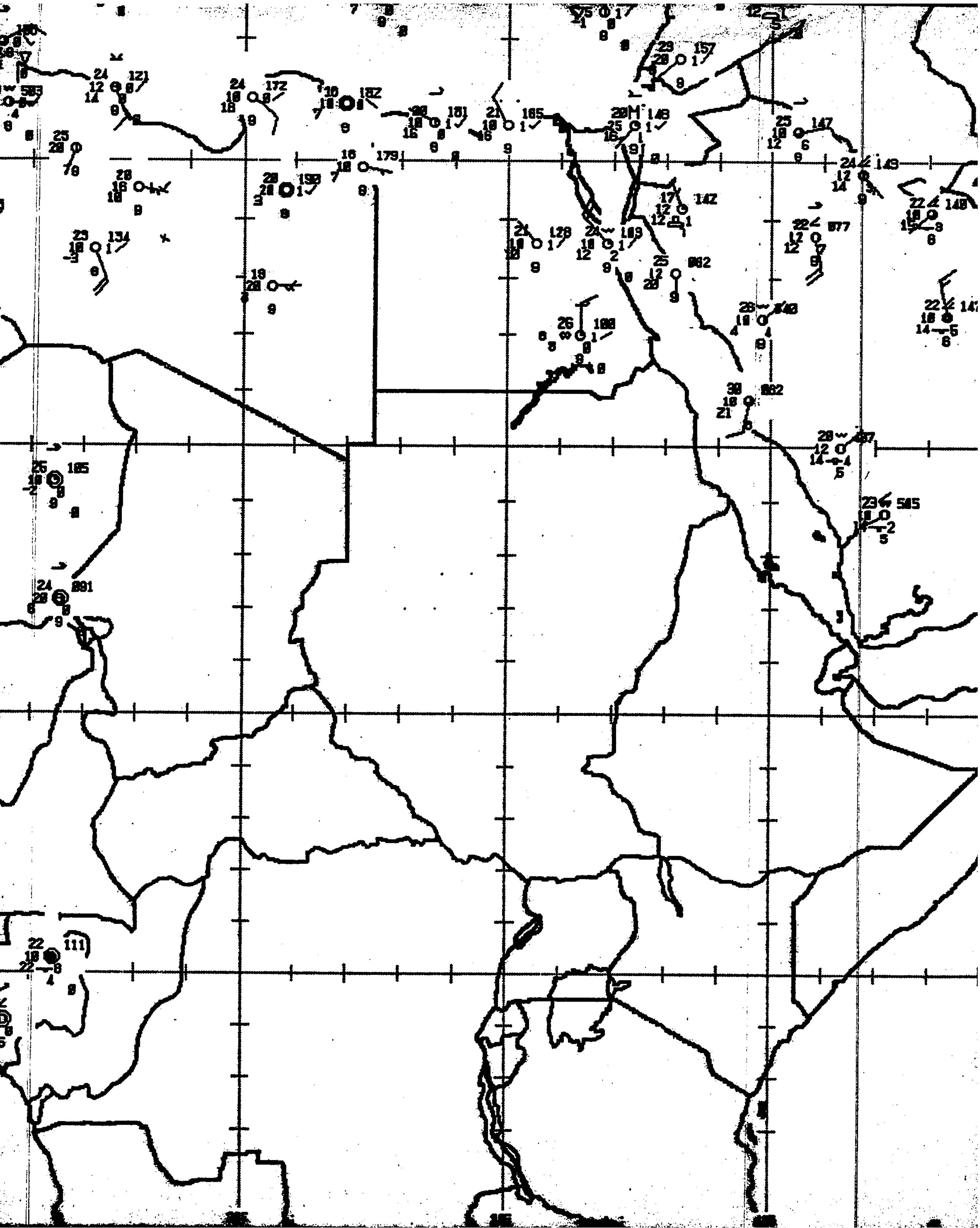
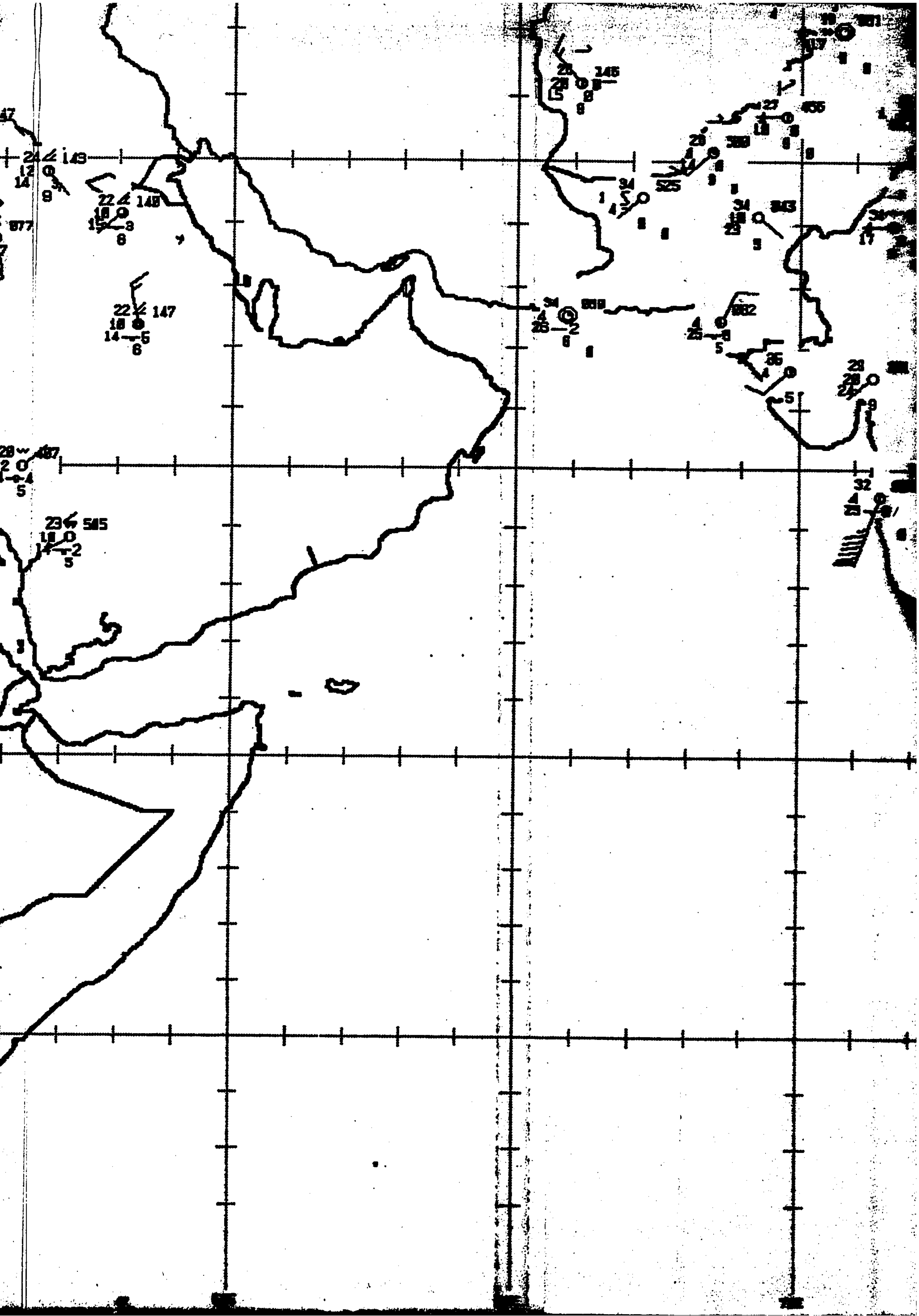

50N
40N
30N


20E
30E
40E


50E
60E
70E


30N
20N
10N





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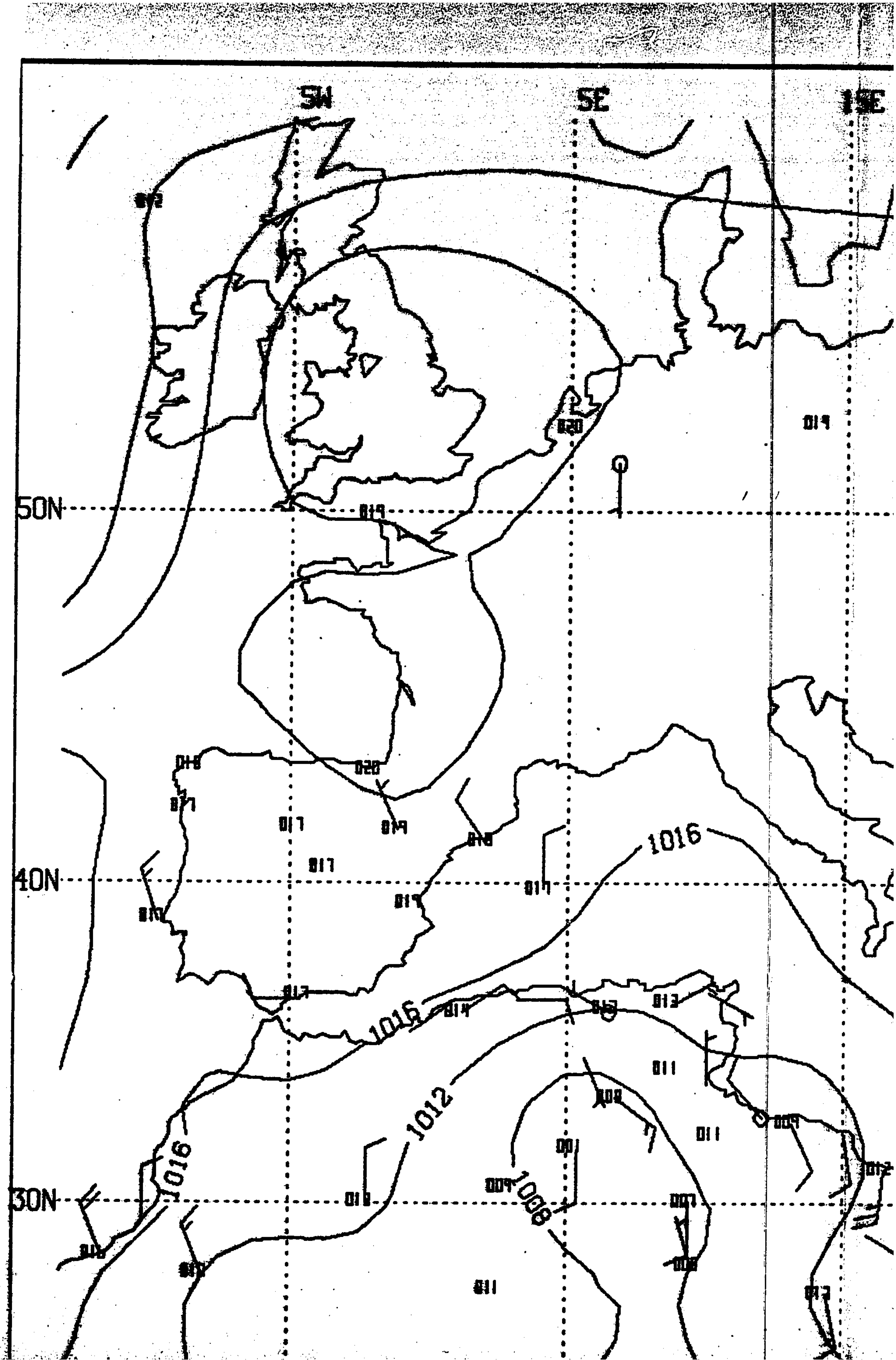
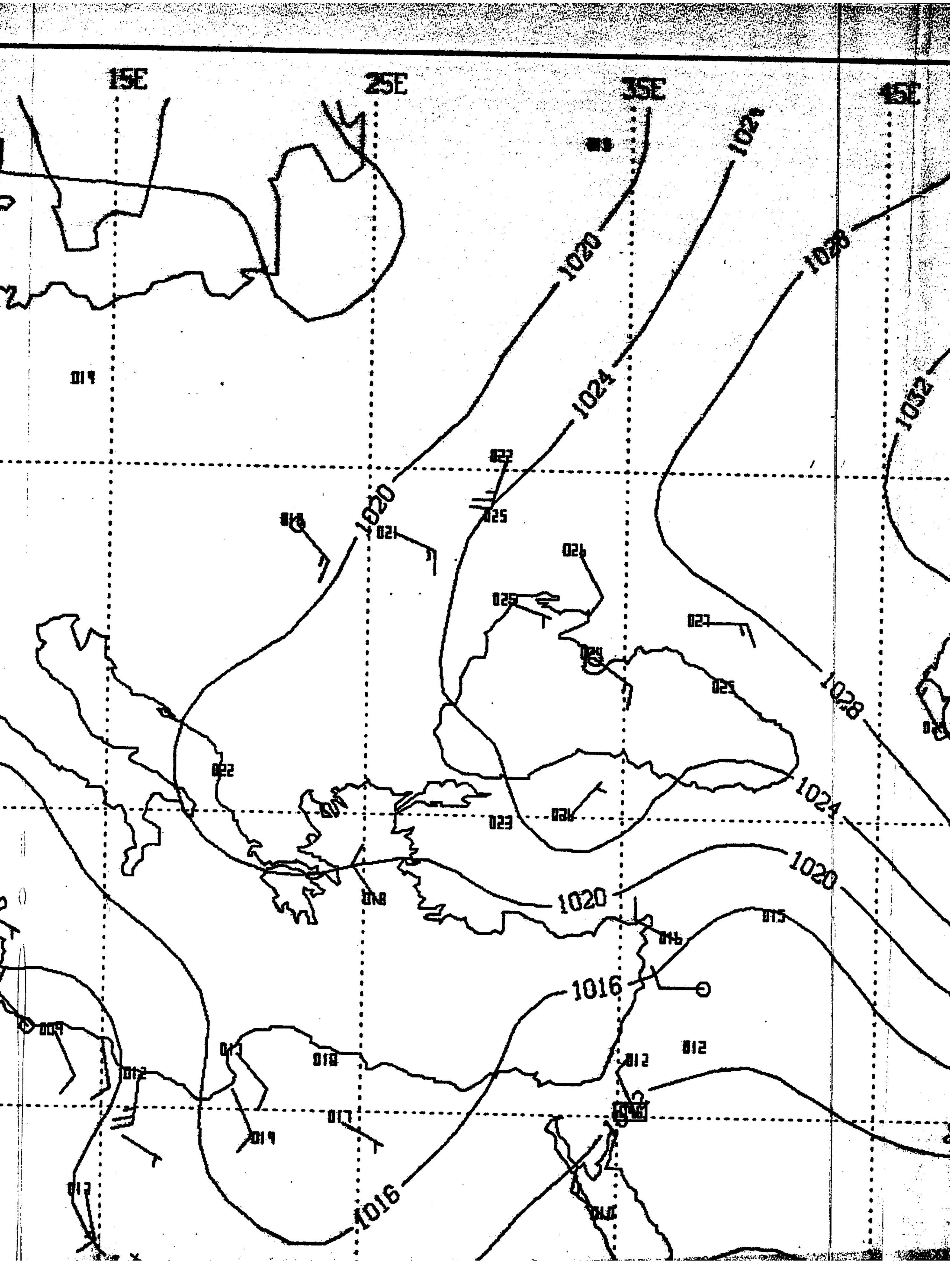
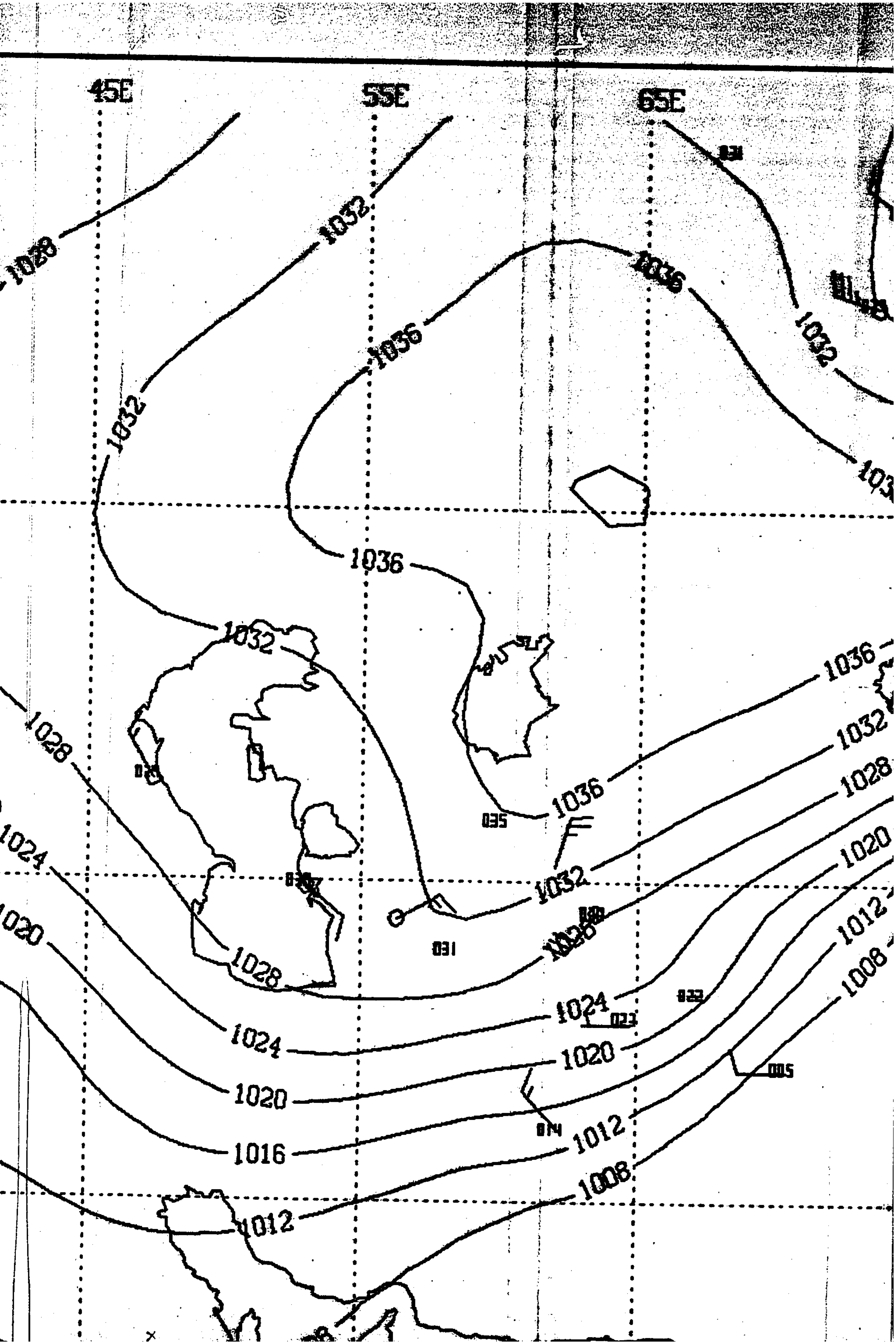


5W
5E
15E
50N
40N
30N
1016
1016
1016
1012
1008



15E
25E
35E
45E
1020
1024
1028
1032
1016


45E
55E
65E
1028
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1020
1012
1008
1036
1032
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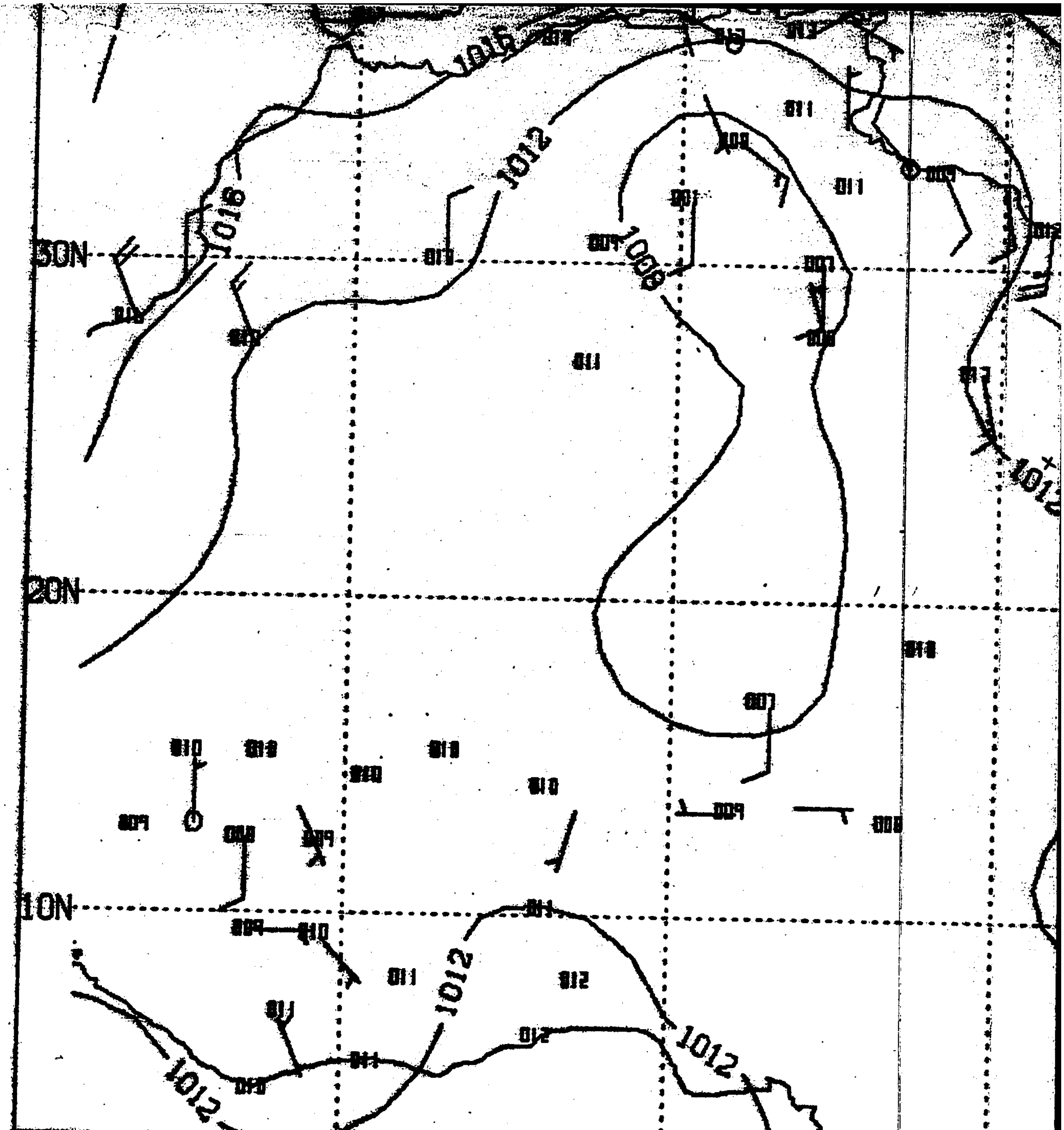
1012
1008
035
031
014
005
022
023



DATE: 10/05/1982

SLP MB

ISSUED AT: 0600 GMT

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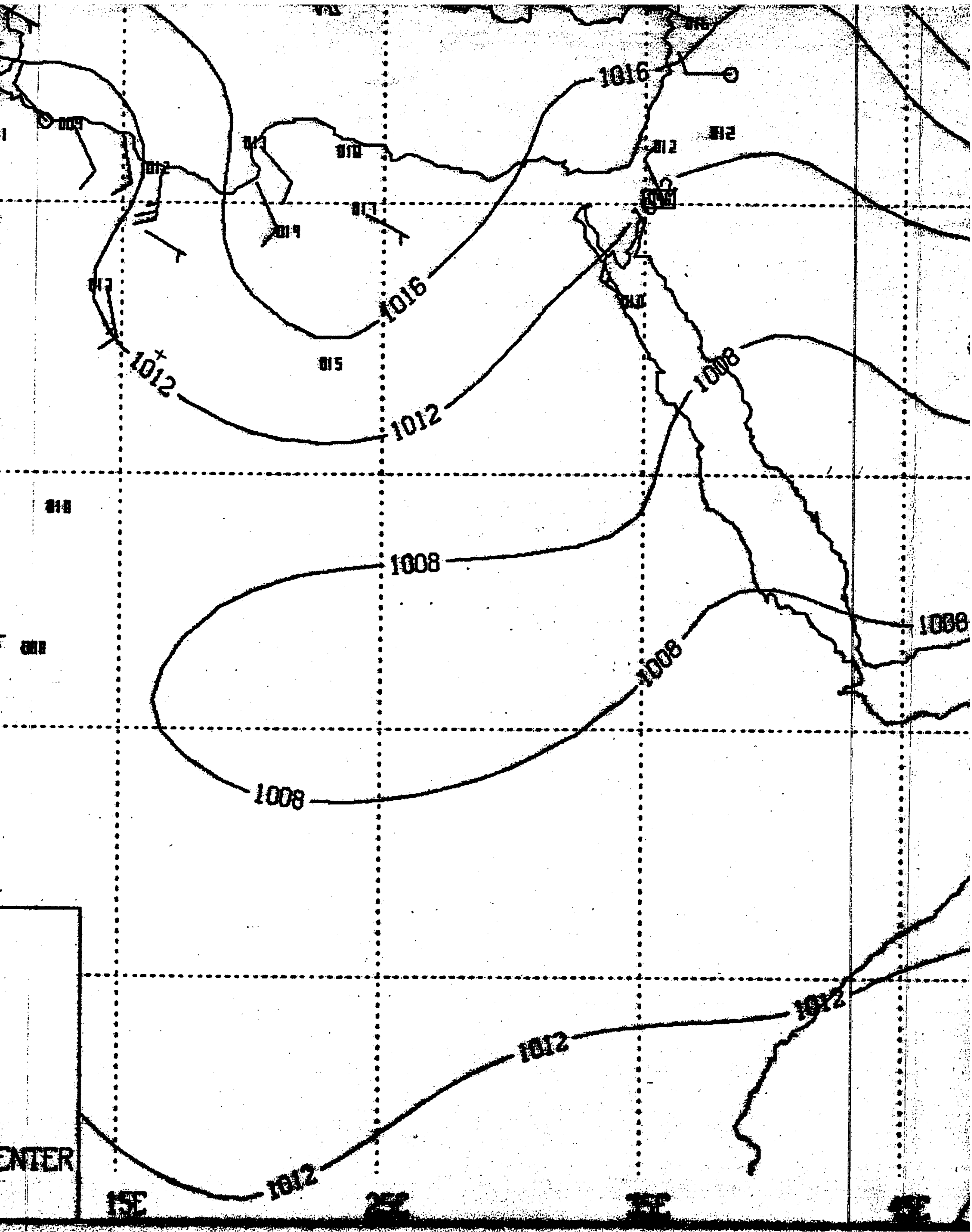
KINGDOM OF SAUDI ARABIA


1016
1016
1012
1012
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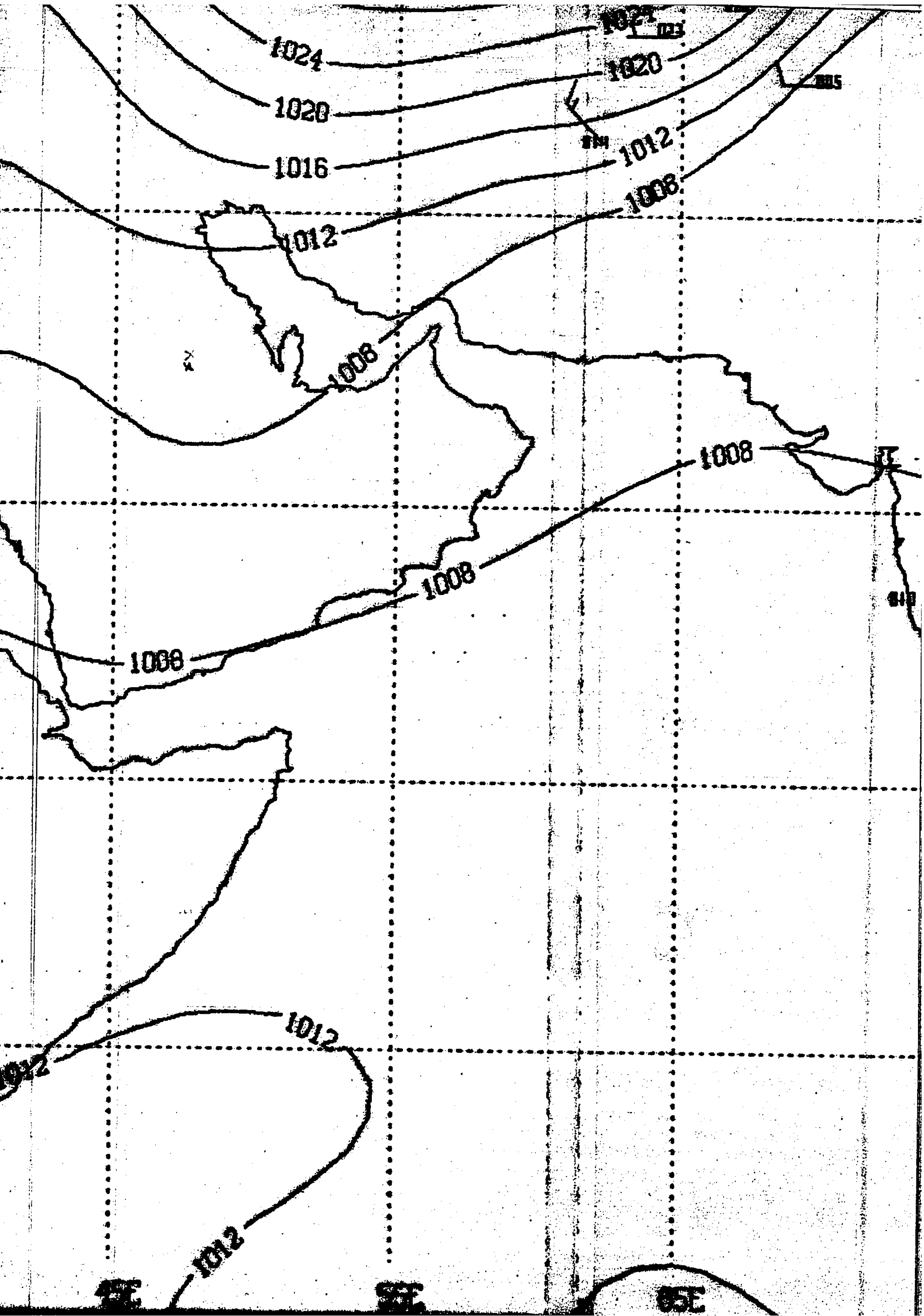
1012
1012
ENTER
15E
25E
35E
45E



1024
1024
1020
1020
1016
1012
1012
1008
1008
1008
1008
1008
1012
1012
1012
45E
55E
65E

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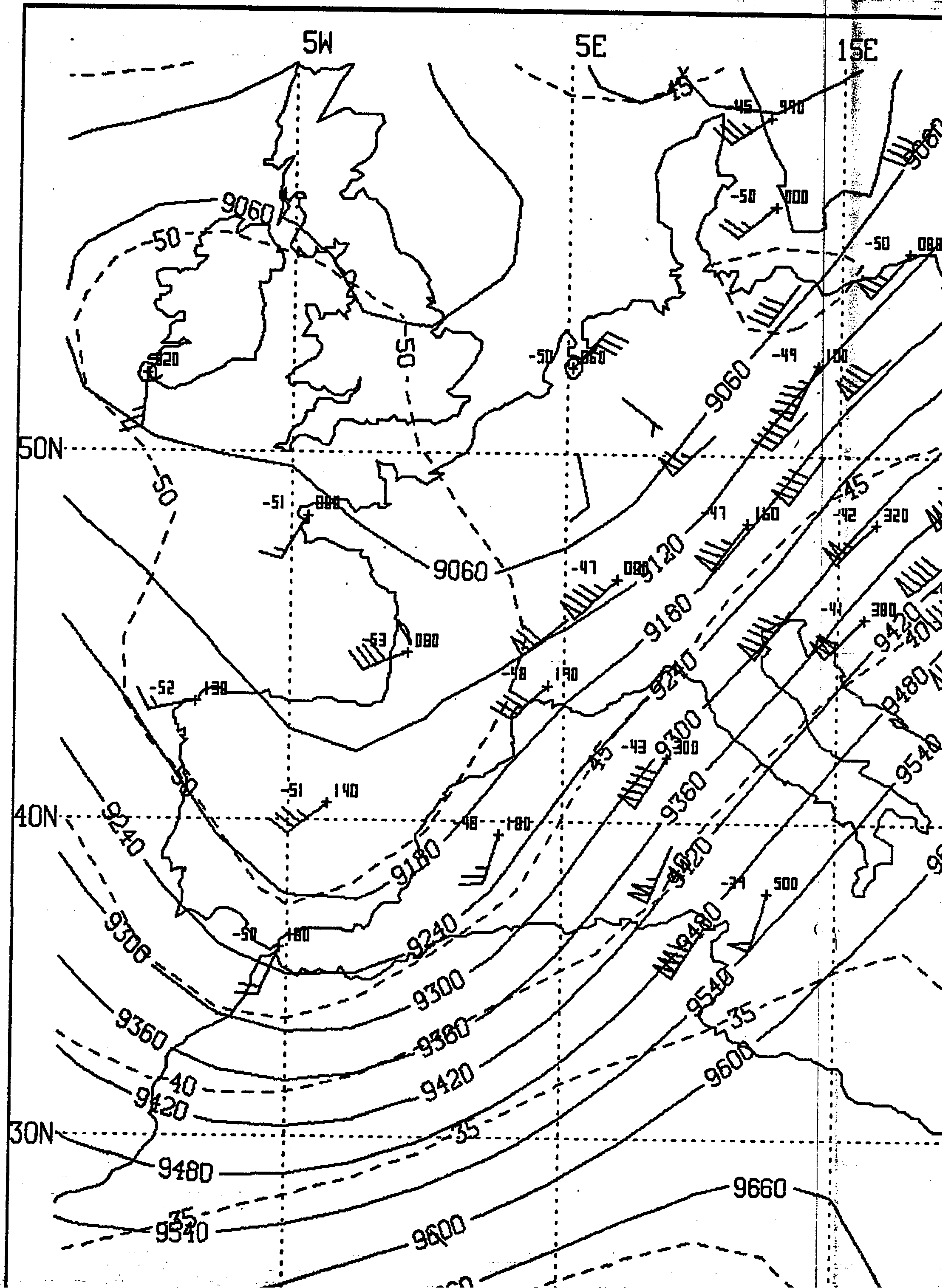
5W
5E
15E
50N
40N
30N
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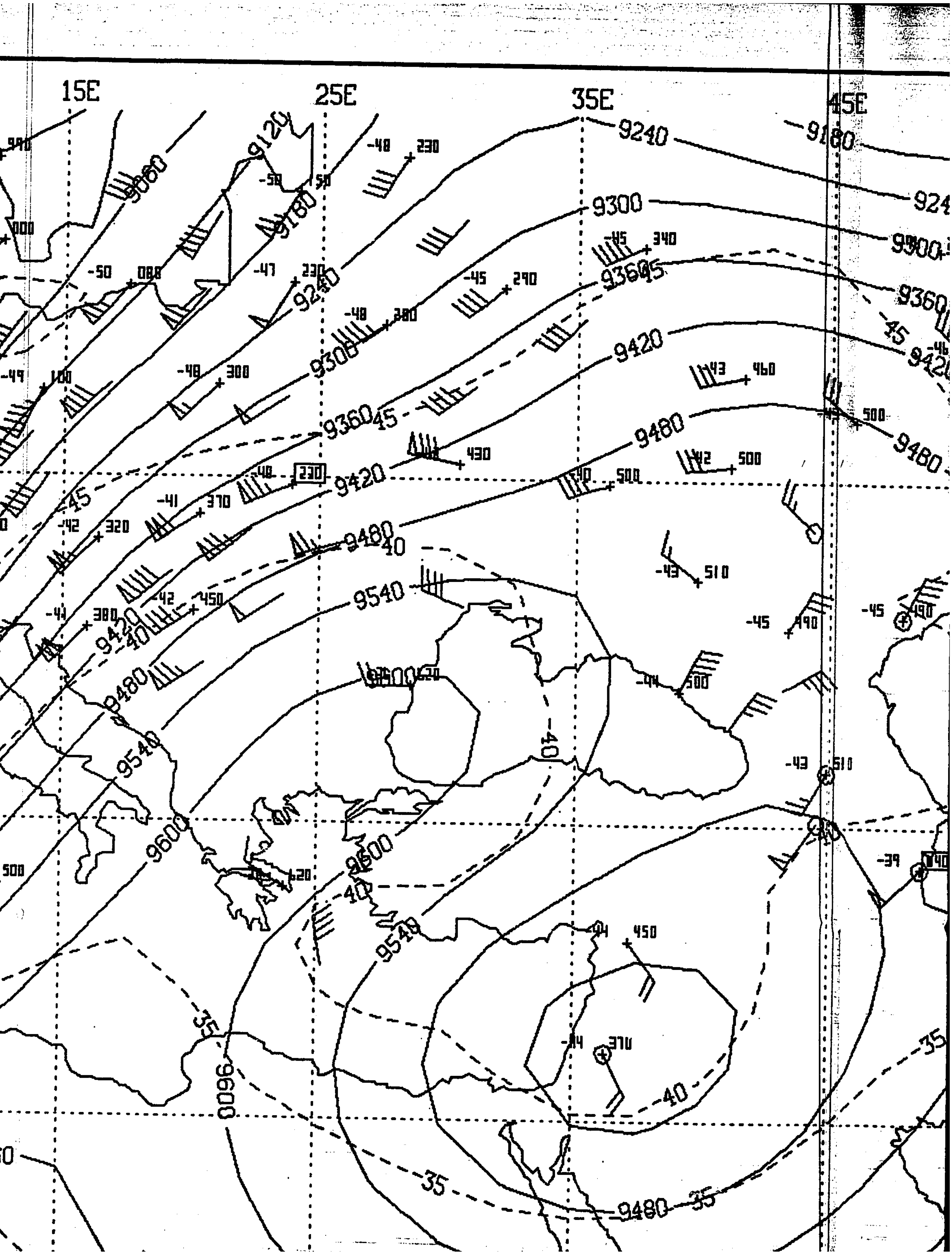
-50
-45
-40
-35



15E
25E
35E
45E
9060
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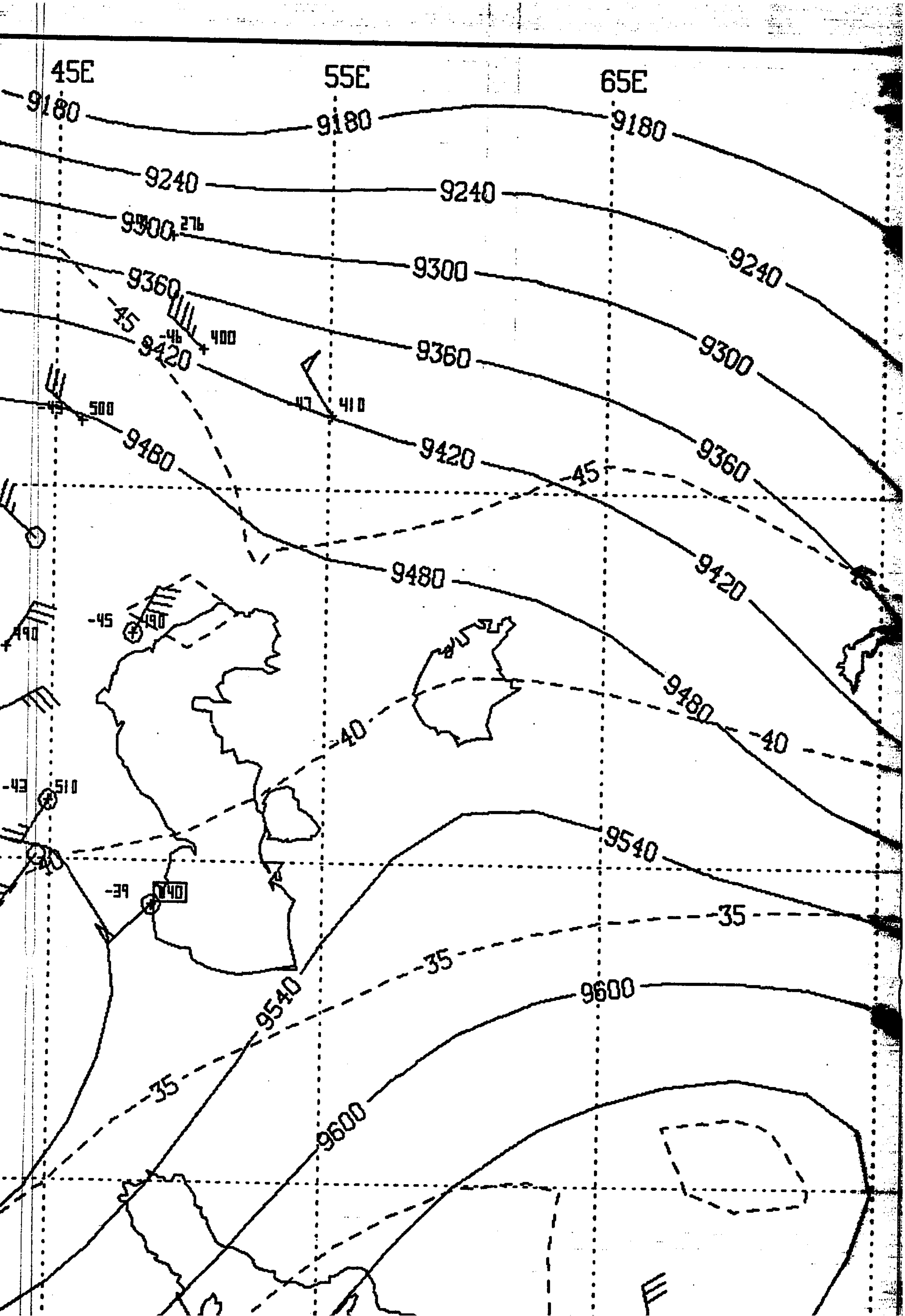
40
35



45E
55E
65E
9180
9180
9180
9240
9240
9240
9300
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9420
9420
9480
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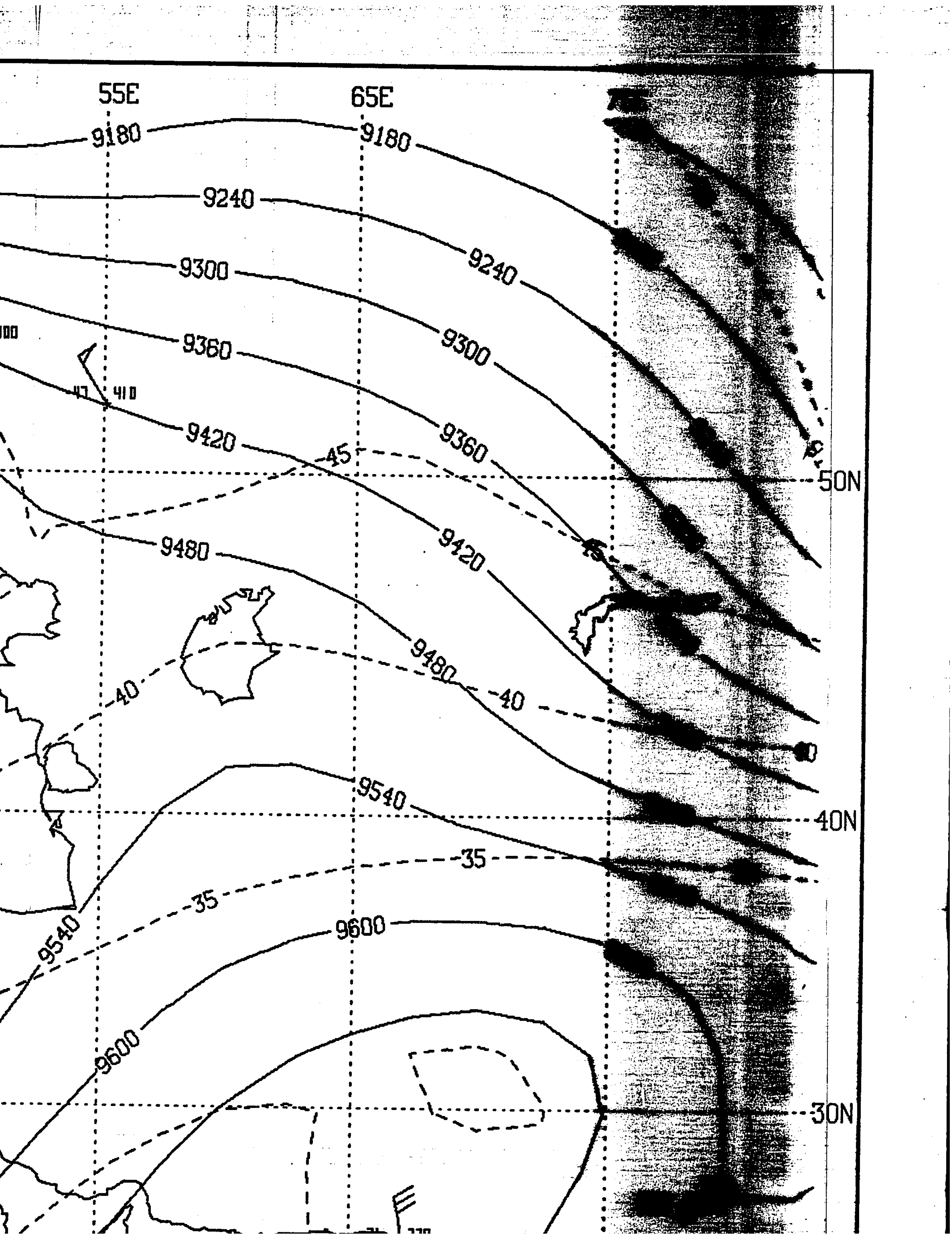
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40N
30N
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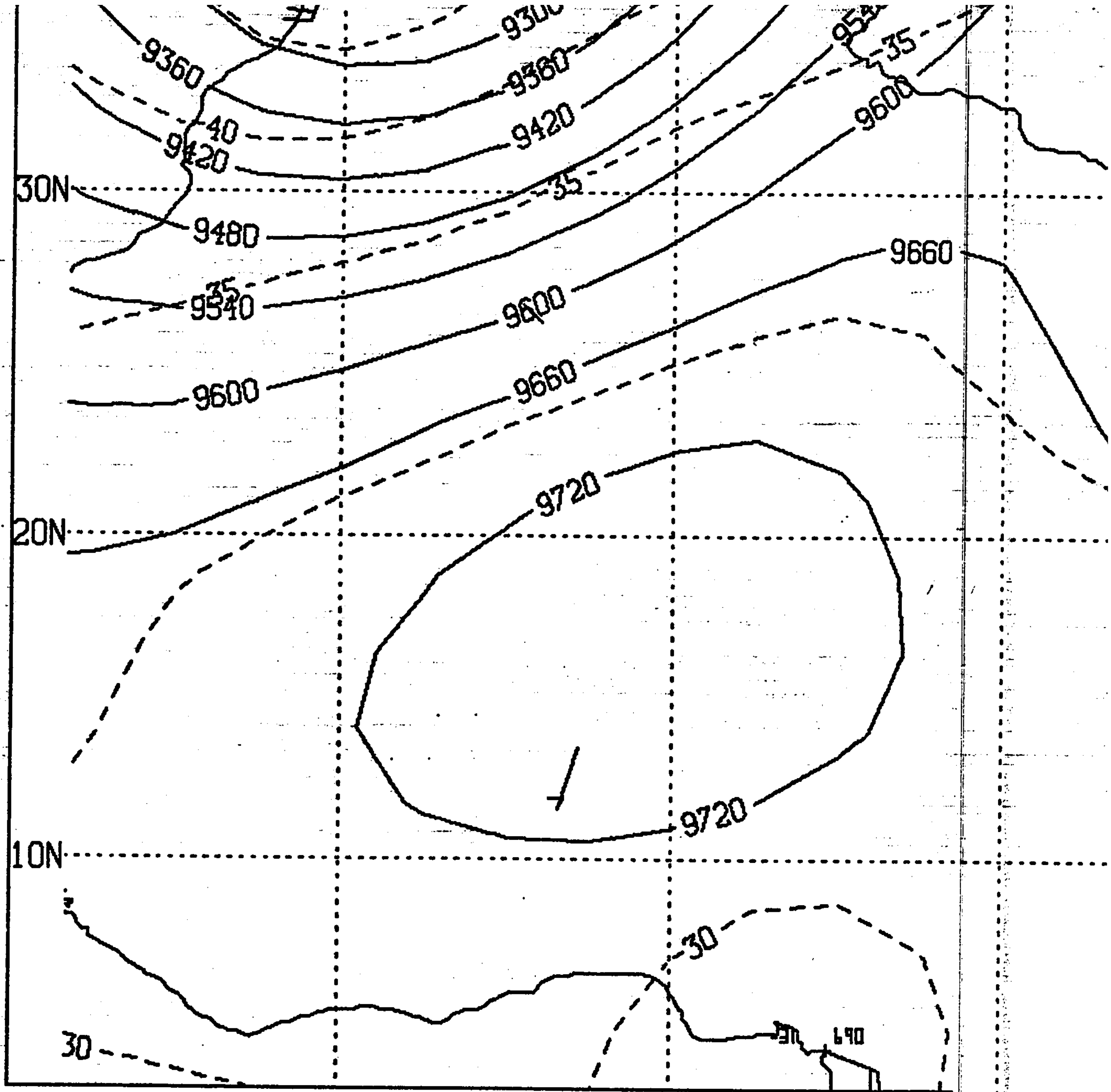

DATE: 10/05/1982

300 HT METERS

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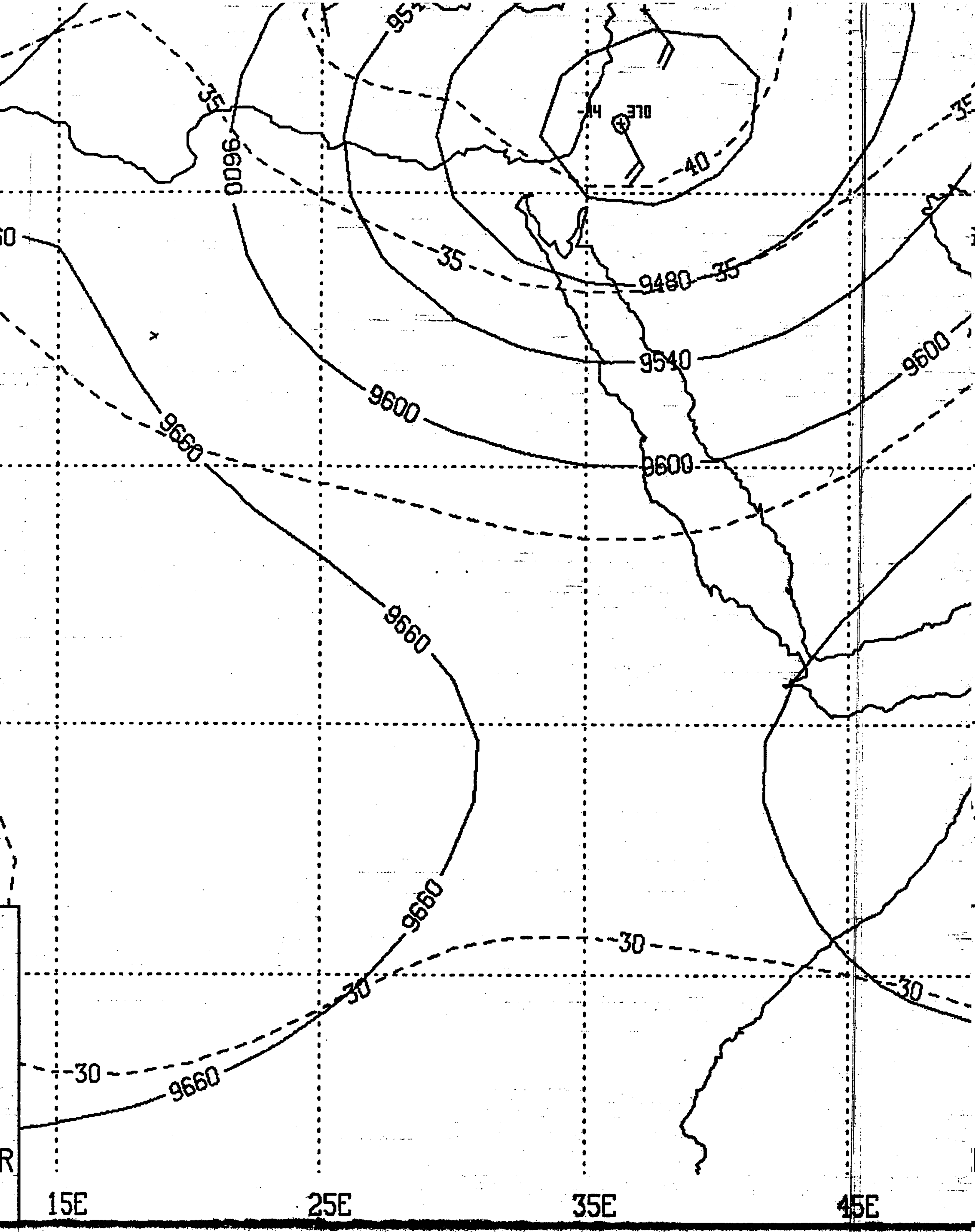

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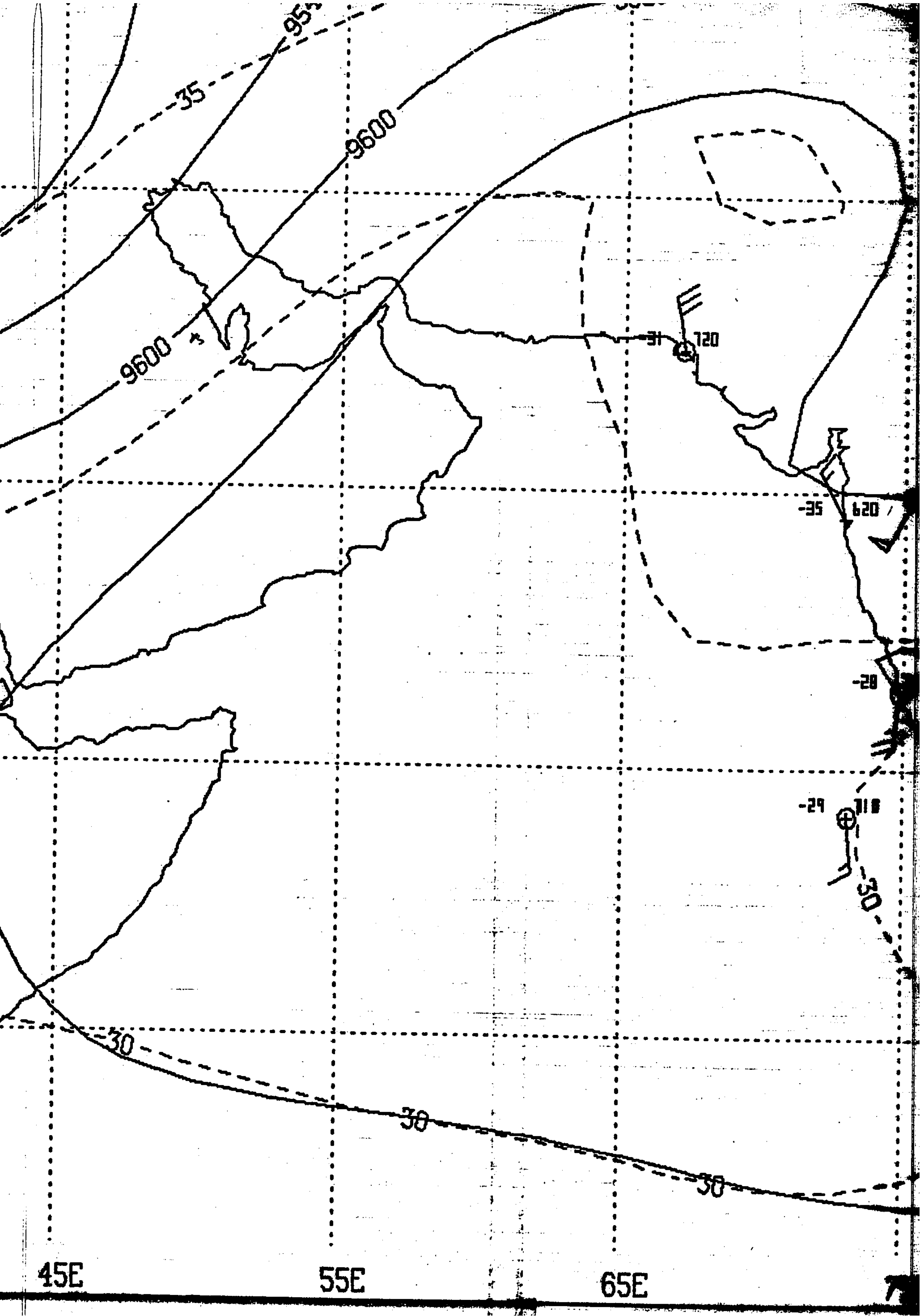
25E
35E
45E



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9600
9600
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720
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-29
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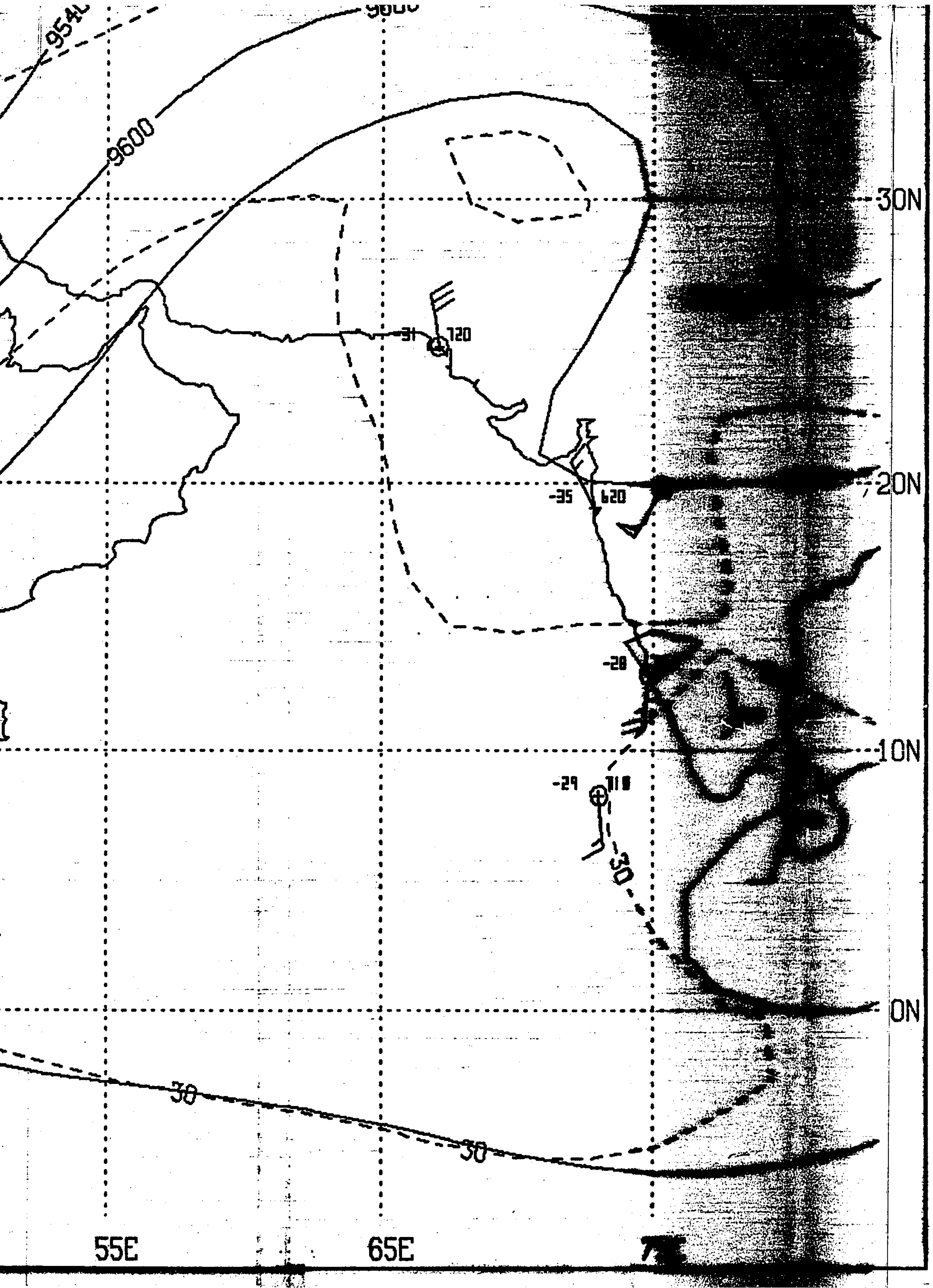
30
30
30
30
45E
55E
65E



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9600
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0N
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620
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-29
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55E
65E
75E